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On some Observations of Jupiter in 1871–72.

By John Browning.

From the drawings of *Jupiter* which I have made since December 1871, I have selected only four to bring before the notice of the Society: these drawings were made on the following dates: No. 1, on Dec. 4th, 1871, at midnight; No. 2, on Jan. 14th, 1872, 7 P.M.; No. 3, on March 3rd, 1872, at 8.45 P.M.; No. 4, on May 5th, 1872, at 9.15 P.M.* Many of the drawings made during the winter months are somewhat deficient in detail as compared with those made recently; but this, I do not doubt, is principally the result of the bad definition due to very unsteady air, as the first drawing mentioned, that made on Dec. 4th, contains nearly as much detail as those made recently; the markings are, however, so complex that they defy all attempts to draw them correctly. I had some tolerably good views of the planet earlier than December last year; the tawny colour of the equatoreal belt seemed to me stronger than I had previously seen it; as, however, a well-known observer, who had previously made colour observations of *Jupiter*, did not agree with me, I preferred making a continuous series of observations before giving a decided opinion on the subject. Subsequent observations have convinced me that my conclusion was correct, and I have since been fortified in this opinion by the statement of our late President, Mr. Lassell. On every occasion when the definition has been good, I have been able to make out light markings flecking the

* The four drawings were exhibited at the meeting in June. Nos. 2 and 4 are reproduced on a reduced scale in the accompanying illustrations.

tawny-coloured surface of the equatoreal belt. The drawings I have made do not show any remarkably symmetrical forms ; in several instances I had drawn nearly oval markings or turreted forms on the southern edge of the equatorial belt, but using the highest powers the night would bear, and watching for fitful intervals of the best definition, I always found these exceedingly regular forms were incorrect, and had to modify them : for this reason I rather distrust the drawing made on the 3rd of March. The markings on the dark belt, south of the equator, present forms similar to those we see at times in white cumulus clouds previous to a thunder-storm. I believe that could I have obtained clearer views of the planet, I should not have left these markings quite so regular as they now appear in the drawing. When favourably seen, such markings usually terminate in points or rugged edges towards the W. The light belts frequently incline at a considerable angle from the poles towards the equator of the planet. The belt shown on the drawing No. 4, made on May 5th, at 9.15 P.M., G. M. T., makes an angle of nearly 25° with the equatorial belt ; a number of shorter markings, also, at about the same angle, stretch some distance into the tawny-coloured equatorial belt ; these I at first drew of a turreted form, and only very close examination convinced me that they had the inclination I have now given to them. The darker belts have varied from dark warm or cool grey, to purple madder, or madder brown; but towards the poles of the planet the belts have been usually bluish grey, while close to the poles the blue colour has been very decided. During the month of May the colour of the equatorial belt had seemed fainter, but this is probably due to the planet being less favourably situated for observation.

I have made several observations of the spectrum of the planet, but though I have 12 inches of aperture, I do not find this sufficient to enable me to see more than the dark absorption bands in the red portion of the spectrum, with which most observers are now probably familiar. Though I cannot make out any differences in the appearance of the spectrum sufficiently marked to enable me to draw or describe them, yet I strongly suspect a change in the spectrum, which a larger aperture, giving more light, would enable me to bring out.

On the Masses of the Planets and the Parallax of the Sun.

By M. Le Verrier.*

The exact determination of the angle π, or the solar parallax is a matter of great interest to astronomers ; it is the maximum angle under which an observer, supposed to be placed at the Sun's centre, would see the radius of the terrestrial globe.

* Translated from the *Comptes Rendus* for 1872, July 22, by W. T. Lynn, B.A., F.R.A.S.

The solar parallax being known in sexagesimal seconds, it is only necessary to find how many times it is contained in the number 206265, to conclude from it the Sun's distance from the Earth, referred to the radius of our globe as unity.

Laplace, in common with the other French astronomers of his epoch, adopted in the *Mécanique Céleste* the parallax $8''{\cdot}813$, derived from the transits of *Venus* observed in 1761 and 1769. From this it had been concluded that the Sun's distance from the Earth was 23405 radii of the Earth.

Afterwards Encke, having re-discussed the observations of those transits, determined that the parallax was only $8''{\cdot}578$, and that the Sun's distance ought consequently to be regarded as 24046 terrestrial radii.

It has been perceived that the change made by the Berlin astronomer in Laplace's number was not a happy one, and that, instead of taking anything away from it, the value $8''{\cdot}813$, attributed to the solar parallax in the *Mécanique Céleste*, should rather have been increased by some hundredths of a second.

Whether the Sun's distance from the Earth is greater or less by a small fraction of its amount, is not, considered in itself, a matter of such great interest. But the knowledge of the solar parallax is useful in many astronomical calculations : in particular, it gives the means of determining the value of the Earth's mass, and of taking account of its action upon the Moon, by introducing it into the calculations of the *Mécanique Céleste.*

Newton has furnished for this purpose a method which comes, in fact, following the *Mécanique Céleste*, to the employment of the formula

$$m = 4{\cdot}4320 \left(\frac{\pi}{1000}\right)^3,$$

m being the value of the Earth's mass referred to that of the Sun as unity.

If we admit $8''{\cdot}813$ as the value of π as the parallax, we find that the ratio of the mass of the Earth to that of the Sun is $\frac{1}{329630}$. The reduction of $\frac{1}{38}$th, proposed by Encke in the value of the parallax, would lead us to attribute to the Earth a mass less by $\frac{1}{13}$th than that which we have just given.

The preceding formula may also be solved with respect to π, which gives

$$\pi = 608{\cdot}79\sqrt[3]{m}.$$

This shows that if we could determine directly the value m of the Earth's mass, we could deduce the solar parallax therefrom.

If we set out by determining the parallax, the relative error that may be committed becomes threefold in the deduction of the value of the mass of the Earth.

If, on the other hand, we commence by determining the Earth's mass, the relative error in the deduction of the parallax becomes three times smaller. An error of $\frac{1}{300}$ in the value adopted for the Earth's mass corresponds to an error of $\frac{1}{900}$ in

the value concluded for the parallax, that is to say, to very nearly 0″·01.

The attraction of the Earth produces sensible inequalities in the motions of *Venus* and *Mars*. By determining the amplitude of these by observations, it is possible to conclude directly from them the mass of our planet. It may be worth while to examine to what degree of exactitude we can arrive by this means.

To increase the precision of the result, we may unite the consideration of the periodic inequalities with that of the secular inequalities.

The elements of the orbits of *Venus* and *Mars* undergo variations called secular, which increase from year to year, from century to century, and at last acquire very large values, which renders them very suitable for resolving the question with which we are now occupied. It may even be said, *à priori*, that their consideration offers a method which ought, *in the course of time*, to equal in precision that which may be expected from the direct measure of the solar parallax, and at last even to exceed it. Let us inquire whether this epoch may not have now arrived.

At the time of the celebrated transits of *Venus* over the Sun in 1761 and 1769, Bradley had, ten years before, commenced the series of meridian observations which Maskelyne, Pond, and Airy have continued to the present time without interruption. By establishing at Greenwich the instrument invented fifty years before by Roemer, Bradley secured for England the possession of one of the fundamental bases of exact astronomy. This is what might have been done for France from the commencement of the eighteenth century.

The labours of Bradley gave the means of determining with accuracy the elements of the orbits of *Venus* and *Mars* for the epoch 1755. But nothing else of a precise nature was possessed in the way of observations, and it was necessary that long years should elapse before it was possible to demonstrate and measure the *variations* of the elements of the orbits. One hundred and twenty-one years have now passed away since Bradley's observations were made.

The variations of the excentricities, of the perihelia, of the inclinations, and of the nodes of *Venus* and *Mars*, may all be made to contribute to the result. Let us pause at the most important, that of the perihelion of *Mars*. The planet is in a position to be observed with great accuracy at its oppositions ; and, moreover, we possess a triple simultaneous observation made on the 1st October, 1672, by Picard, Roemer, and Richer, which extends to two hundred years the period of which we are able to avail ourselves.

The attraction of the Earth changes by 50″ in a century the heliocentric position of *Mars*' perihelion.

When *Mars* is actually in opposition, this change subtends at the Earth an angle of 185″.

The variation in two centuries and for the position of the

planet *Mars* on the 1st of October, 1672, is, seen from the Earth, 294″ of longitude.

The discussion of the great series of meridional observations leads us to estimate that we can generally deduce from them, within a second, the value of the geocentric errors resulting from the consideration of the whole mass of observations. We may, therefore, consider that the epoch has arrived when the direct determination of the Earth's mass can be obtained, by the employment of the secular variations of the elements of the orbits of the planets, with a precision at least equal to that afforded by the direct observation of the Sun's parallax.

Let

$$(1)\quad \begin{cases} m = 0{,}000000333\,(1+\nu) & \text{Mercury,} \\ m_1 = 0{,}000002489\,(1+\nu_1) & \text{Venus,} \\ m_2 = 0{,}000002817\,(1+\nu_2) & \text{The Earth,} \\ m_3 = 0{,}000000373\,(1+\nu_3) & \text{Mars,} \\ m_4 = 0{,}000952381\,(1+\nu_4) & \text{Jupiter,} \end{cases}$$

represent the real masses of *Mercury*, *Venus*, the *Earth*, *Mars*, and *Jupiter*; the numerical co-efficients representing the values of the masses which in the *Annales* have been used as starting-points, and ν, ν_1, ν_2, ν_3, ν_4, being the indeterminate quantities to be investigated by making them satisfy the observations.

The mass of *Mercury* results from the perturbations which that planet produces in the motions of *Venus*. The discussion of the observations made at Greenwich from 1751 to 1761, and from 1766 to 1830, furnishes as equation of condition :—

$$(2)\qquad 18''{\cdot}2\,\nu + 30''{\cdot}1\,\nu_1 + 35''{\cdot}35\,\nu_2 + 3''{\cdot}55 = 0.$$

Venus changes the position of the plane of the ecliptic. In order to satisfy the observed motion, we have the equation :—

$$(3)\qquad +0''{\cdot}53\,\nu + 28''{\cdot}88\,\nu_1 + 0''{\cdot}83\,\nu_2 + 1''{\cdot}72 = 0.$$

The mass of *Mars* results from the discussion of the meridional observations of the Sun. This gives

$$(4)\qquad \nu_3 - 0''{\cdot}016\,\nu + 0''{\cdot}484\,\nu_1 + 0''{\cdot}071 = 0.$$

The observations of the fourth satellite of *Jupiter* and the perturbations of the system of small planets furnish the value

$$(5)\qquad \nu_4 = +0''{\cdot}0012.$$

The mass of the Earth enters advantageously for its determination in three relations.

The first (A) of these relations * results from the latitudes of

* In the original, a misprint 'rotations.'

Venus at the moments of the transits in 1761 and 1769. It is independent of the uncertainty in the apparent diameter of the Sun, and possesses an extreme precision :—

$$(A) \quad -0''{\cdot}53\,\nu + 24''{\cdot}6\,\nu_1 + 32''{\cdot}8\,\nu_2 - 1''{\cdot}86 = 0.$$

The second (B) is furnished by the discussion of the meridional observations of *Venus*, in an interval of one hundred and six years :—

$$(B) \quad -0''{\cdot}76\,\nu + 24''{\cdot}6\,\nu_1 + 32''{\cdot}9\,\nu_2 - 2''{\cdot}00 = 0.$$

This agrees very nearly with the first (A), which is a proof of the accuracy, both of the observations themselves and of their discussion.

Lastly, we will deduce the third or (C) from the observations of the 1st of October, 1672. Richer at Cayenne, Picard near Beaufort, and Roemer at Paris, all compared *Mars* with the star ψ *Aquarii*, which was then occulted by the planet. Their separate comparisons differ respectively only by the very small quantities $0''{\cdot}5$, $0''{\cdot}8$, and $0''{\cdot}3$. On the other hand, Bradley has left us thirty-two meridional observations of the three stars ψ, ψ', and ψ^2 *Aquarii;* we have discussed these with great care, and here also there is every guarantee of accuracy :—

$$(C) \quad 225''{\cdot}3\,\nu_2 + 29''{\cdot}5\,\nu_1 + 1398''\,\nu_4 - 21''{\cdot}86 = 0.$$

If, making use of the equations of condition (2) (3), (4) and (5), we eliminate the indeterminate quantities ν, ν_1, ν_2, ν_4, we derive from this process, by means of each of the equations of condition (A), (B), (C), treated separately, the following values for the ratio $1 + \nu_2$ of the new mass of the Earth to that which was adopted as the starting-point ; also for the value of the solar parallax deduced therefrom :

	$1+\nu_2$	Deduced Solar Parallax.
(A)	1,0917	$8''{\cdot}853$
(B)	1,0937	$8''{\cdot}859$
(C)	1,0965	$8''{\cdot}866$

It is well known that L. Foucault has found, by direct measurement of the velocity of light, adopting the constant of aberration determined by Struve, the number for π, $8''{\cdot}86$.

It appears from these results that the epoch has really now arrived when the value of the mass of the Earth, which ought to be introduced into the calculations of the *Mécanique Céleste*, can and should be derived directly from the motions of the planets, and no longer though the intervention of the solar parallax.

But it may be asked, does it follow that it is legitimate to conclude from the former by a reciprocal process the value of the solar parallax itself? Undoubtedly it would be, if we were certain that the celestial bodies which we take into account were

the only ones that could come into consideration. But, whatever reasons we may at present have for regarding the aggregate mass of the minor planets as extremely small, it is nevertheless possible that their attraction, continuing to accumulate in the course of time, may at last become sensible; and it is proper to ask whether a proof of this can be found in the difference between the values of the parallax determined from the discussion of the movements of the celestial bodies, from the measurement of the velocity of light and of aberration, and lastly, from the observation of the transit of *Venus* over the Sun's disc. It is not easy to answer this question; it depends upon the magnitude of the unknown influence, the determination of which is itself the matter under consideration.

If the discussion of the motions of the celestial bodies should give a value of the parallax larger by $\frac{1}{10}$th of a second than that which is deduced from the velocity of light, and than that which may be deduced from the transits of *Venus*, we might attribute this difference to the attraction of the minor planets, and so measure the amount of their influence. But if this influence is represented by a result corresponding only to $\frac{1}{100}$th of a second in the value of the solar parallax, all that could be concluded would be that the total mass of the minor planets is excessively small, but that its actual amount could not be measured.

Such may, in fact, be the case. The attraction of the minor planets must certainly, if sensible at all, be much more so in its effect upon the planet *Mars* than upon *Venus*. And since the discussion of the observation of *Venus* leads us to the same result, as that of the observations of *Mars*, and since also this result is the same as that derived by Foucault from the velocity of light, it appears very probable that the attraction of the minor planets amounts up to the present time to a quantity which may be neglected.

But it is necessary here to remark that as the angular errors introduced by the perturbations in the positions of the planets *Mercury*, *Venus*, the Earth, and *Mars*, go on constantly increasing, in the course of time an epoch must arrive when it will no longer be possible to put all these quantities in accord with each other, without perhaps introducing new forces. This is even now certainly the case with respect to regions situated between *Mercury* and the Sun. Thus there is a considerable quantity of matter which has hitherto escaped our regular investigations.

These things being so, it seems that Astronomy ought to enter upon a path somewhat new; and I would venture to ask the Academy to interest itself in a number of pieces of work which have now become necessary.

(1.) In the first place, it is necessary to open what we will call, the better to express clearly our idea, *the taking account of celestial masses*.* For this purpose, going back into the past, we should inquire with care the circumstances under which per-

* In the original, 'Le compte des matières célestes.'

turbing actions peculiar to such and such a planet have produced remarkable perturbations, and establish the equation of condition which results from this for the determination of its mass. In doing so, use ought to be made of all the past observations made at different observatories.

At the same time the most favourable future circumstances for the determination of masses ought to be investigated, and made known to astronomers beforehand, so as to secure obtaining the necessary observations.

Thus would result a union of conditions, the fruits of which would accumulate daily, and lead to the most important results.

(2.) We would ask physicists again to take up the *direct* measurement of the velocity of light. The Academy would without doubt obtain this from M. Fizeau.

(3.) The determination of the constant of aberration ought to be an object of attention to astronomers; it would be very interesting, at a time when the constant determined by M. Struve plays so special a part, to be possessed of the grounds of the opinion of that eminent astronomer on the degree of accuracy which he is sure of having attained.

(4.) Lastly, the determination of the solar parallax by means of the transits of *Venus* still retains all its interest, but conditionally on its being made with exceptional precision, so that the astronomer may be able to answer for it with an accuracy corresponding to $\frac{1}{100}$th of a second of arc, or about the $\frac{1}{900}$th part of the total value of the parallax.

With this limit of extreme precision the labour becomes one of the most delicate works of art, and one which ought only to be confided to men who have given special guarantees of their devotion to the enterprise, and who have themselves resolved to carry out the observations. We think the Academy should name these without delay, leaving to them the whole of the responsibility, but also providing them with every assistance in procuring the means of execution.

After the reading of this paper, some remarks were made by M. Fizeau and M. D'Abbadie on the question of the desirability of re-determining the velocity of light by the method of Foucault. M. D'Abbadie said that Foucault's result was, in fact, a happy coincidence. The base selected by that ingenious physicist was so small (only two or three metres, in fact, in length) that any error made in measuring it was enormously increased in the determination of the resulting velocity. But M. Fizeau had previously invented a much better method which rendered it possible, by selecting suitable stations, to take a base of more than 100 kilometres, which geodeters can measure within a decimeter. In making a new determination, M. D'Abbadie thought it extremely desirable to use this method in preference to the much less exact one of Foucault.

Observations made during the Eclipse of June 6, 1872. By A. Nursing Row, Esq.

(*From a Letter to Dr. Huggins.*)

I have the pleasure to enclose a copy of the paper printed by me, with the particulars of the solar eclipse of the 6th instant, for the use of my friends and the community, European and native, in the neighbourhood of Vizagapatam. I am sorry to say, that we were denuded *in toto* of the means to observe the first contact, and the greatest phase, the clouds were so dense and threatening rain.

We were in despair until ten minutes to the last contact time, but then the Sun made his appearance from an aperture in the mass of clouds around him, and continued to do so until the last contact was observed most satisfactorily. The error of the prediction for the last contact, according to the observation, was +7 seconds.

The enclosed statement contains the observations of the barometer, the solar radiation, the humidity, &c. for every ten minutes during the eclipse.

The solar radiation observations were made with the black-bulb thermometer that was used the last solar eclipse-time—description of which was given in my last report,* 13th Dec. 1871.

The height of the instrument from the ground, and the character of the ground, are one and the same this time and last time.

The magnitude of the present eclipse is ·927, that of the last eclipse was ·629. With so much sheltering from the Sun's rays by the opaque body of the Moon at the greatest phase of the eclipse, and with those well-known rain-clouds—nimbus covering the whole sky, which will, no doubt, present an obstruction to the free passage of half the solar radiation — I surmised that the radiation thermometer would decrease more than it did at the greatest phase of the last solar eclipse, but it decreased 1°·5 less than it did last time. In addition to the vicissitudes of the season, which create more or less variation of the temperature, there may be various other causes for it.

In this discussion, I think, the altitude of the Sun must be considered. On the date of the last solar eclipse, 12th December, the apparent time of Sun-rising in this latitude was nearly $6^h\ 23^m$. On the 6th instant it was nearly $5^h\ 25^m$. This difference of time in rising compensates the difference of time in the greatest phase of the two eclipses, therefore there is no great variation of the altitudes.

At the nearest approach of the greatest phase last time, the column of the solar radiation thermometer decreased 1·1, but this

* Pages 72 and 73, Vol. xxxii. No. 3, *Royal Astronomical Society's Monthly Notices.*

time only ·5, notwithstanding the magnitude of the eclipse was so great as ·927. In the present case the humidity was apparently great. I wonder what else could cause the less decrease of the column, except the absence of clear sky, and the presence of clouds between the Sun's rays and the Earth, which may probably impede terrestrial radiation also.

Meteorological Observations taken during the time of the Eclipse, 6th June, 1872.

Hours.	Barometer reduced to 32°.	Dry bulb.	Wet bulb.	Humidity.	Solar radiation thermometer.	Kind of clouds.	Clear sky.	Direction of wind.
h m	inches	°	°	cents	°		cents	points
6 3	29·687	88	82	76	51	cu	60	S.
6 13	29·689	88	82	76	51·4	cu	20	S. by W.
6 23	29·695	88·4	82	76	52·4	cu	20	W.S.W.
6 33	29·695	88·2	82	76	51·6	cu	30	S.S.W.
6 44	29·697	88	81·5	74	51·2	cu	20	S.
6 43	29·699	88	81·5	74	50·5	cu	20	S.
7 3	29·699	88	81·5	74	50	N.	„	S.
7 13	29·701	88	81·5	72	49·5	N.	„	S.W.
7 23	29·705	87·8	81·4	76	50·5	N.	„	S.
7 33	29·709	87·7	81·3	76	52·3	cu	20	S.
7 43	29·709	87·7	81	72	54	cu	20	S.W. by W
7 53	29·709	88	81·4	72	55·4	cu	20	S.W.
8 3	29·711	88	81·7	76	57·3	cu	30	S.W. by W.
8 13	29·715	88	81·8	76	59·3	cu	30	S.W. by W.
8 23	29·721	88	81·8	76	63	cu	50	S.W.
8 30	29·720	88·6	81·7	73	76	cu	50	W. by S.

Observations made during the Eclipse of June 6, 1872. By N. R. Pogson, Esq., Government Astronomer at Madras.

(*From a Letter to the Astronomer Royal.*)

I take the earliest opportunity of informing you of our results on the occasion of the annular eclipse of the Sun on the 6th.

Availing myself of your kind encouragement to make use of the Browning reflector, I got the Government to sanction the immediate erection of a sliding flat-roofed room, a dark room, and a printing room, over the transit-circle room, and got all completed just, and only just, in time. My son, assisted by Mr. F. Doderet, got nine photographs altogether—four during the important time. I enclose copies of six: No. 1, partial, before centre; 2, just as the ring was forming, when the coronal light,

shining behind the Moon's disk, made the ring appear faintly completed before it really was so. This was clearly seen also by Ragoonatha Charry with the Lerebours equatoreal, and even by myself and my son with the finders of the Simms' equatoreal and of the Browning reflector. The photograph shows it, but the negative better still. No. 3 shows the complete ring at central time, 4 near its breaking, 5 at the moment, and 6 a partial phase soon after. Nos. 4 and 5 got taken on the same plate by a mistake, but, by placing one in the centre and painting the other out, there is no confusion. No prominences were seen, either by the eye or in the photographs, though the spectroscope indicated plenty about, especially near the spot shown in No. 4.

I resolved to attempt nothing but the spectroscope, and managed far better than at Avenashy in consequence. I wanted to have had the time of first contact from the spectroscope, by the extinction of the usual bright C, D, and F lines of the chromosphere. I can rarely find any part of the Sun's limb on a fine day at which these are not visible, and I thought that the contact of the limbs should extinguish these; but the Sun was too low to be well got at, and, unless the slit were very accurately over the point of first contact, and reduced in length as well as in breadth till it had nearly become a square, I do not believe in a result. At the first internal contact (just after a peep in the finder had shown me the Moon's limb lighted up by the corona) I saw all the dark lines reversed and bright, but for less than two seconds; the thinnest thread of sunlight restored them instantly.

I could see no trace of lines on the Moon's dark centre, but probably this was owing to the flash of ring-light having dazzled my eyes too much, or else atmospheric dark lines would, I suppose, have been there. The sight of beauty, above all, was, however, the reversion of the lines at the breaking up of the limb. *All* lighted up, reminding me of the platinum wire in the Oxford heliometer, seen through the object-glass some distance off, when Mr. Johnson was putting on the battery to read the scale. The duration astonished me—five to seven seconds; and they faded out gradually, not momentarily. I had even time to turn the micrometer cross-wires upon the most brilliant line of all, which I took for C at the moment, but which the reading clearly showed was B when all was over.

I think these results will interest you; and besides ordinary records, which were duly cared for and will all be ready in due course, I know of nothing else to be expected from an annular eclipse.

The negatives shall be forwarded with these of the Avenashy expedition as soon as the Report is ready; but these eclipses are fearful interruptions, and Avenashy completely upset all my arrangements for last year, and this one, so far, as well.

Madras Observatory, June 11th, 1872.

On Future Solar Eclipses. By the Rev. S. S. Johnson.

The following list of eclipses was undertaken, in the first instance, for my own information and curiosity. Any investigation with regard to phenomena a vast number of years hence can only be a subject of mere curiosity; nevertheless, it may not be regarded as wholly uninteresting. If it be said to be needless to have continued the following examination to the end of the twenty-second century, I can only refer to the computations of the transits of *Venus*, of which Delambre has given a list for a period of two thousand years. I may therefore be excused for calling attention to the eclipses for only *three* centuries to come. The chief reason that induced me to do so was to endeavour to discover, if possible, when the next eclipse of the Sun will take place that will be total at London. Although it is now known what will be the date of this phenomenon for England, I believe no attempt has been made to find out when such will be the case at London. The eclipses of 1912 (in one work) and 1916 (in several works) have been referred to as satisfying the conditions. This is now known to be an error. When it is merely desired to *predict* an eclipse, the long and intricate calculations of the present day are not needed: it is enough to know the time approximately, and not to the nearest second. If expeditious tables could be found, giving the time to a few minutes, they would suffice. Such tables, I believe, I have discovered in those given in the eighth edition of the *Encyclopædia Britannica*. First of all, I tried a great number of *known* solar eclipses by them. In only one instance, that of May 26, 1873, have I found them more than nine minutes out in the time of the greatest obscuration, generally very near indeed, and the size of the eclipse has always been correct in every case I have tried. Amongst others, I tried the eclipse of 1140 by them, which was always thought to be total at London, according to Dr. Halley, until Mr. Hind published his computations in the summer of 1871. After computing by these tables in the *Encyclopædia*, I found, upon making a projection, that a crescent was uncovered at the south side of the Sun, showing the shadow must have gone to the north of London. This agreed with Mr. Hind's result. I therefore concluded that these tables would suffice for the purpose. I am not aware of any list of future eclipses extending over many years. In the *Mémoires* of the French Academy (1768) there is a paper by M. du Vaucel on all the solar eclipses visible at Paris from 1767 to 1900. This catalogue was computed from the tables of Mayer for the meridian of Paris, in order to gratify the French king, who was anxious to know whether a total or annular eclipse would happen soon. I have heard of Hallasckha's list of future eclipses, but do not know how far it extends. Beyond the limits of the present century but little mention has been made of eclipses. I do not, of course, forget Mr. Hind's communication to

the *Times*, last year, concerning the tracks of certain of them in the next century, and also of many in the remainder of the present. One he has omitted, that of May 28, 1900, which I believe is total in the south of Spain, and consequently the next occurring within easy distance from this country.* I have seen lists of eclipses to the end of the present century in two or three astronomical works. There was, therefore, no need to give them. I have, accordingly, commenced with the next. As to the main object I had in view—to discover, if possible, when the next total eclipse for London takes place—the eclipses of 2090 and 2151 seem both likely to satisfy the conditions, but in the former case totality takes place by these tables about $5^h\,34^m$, or only about a quarter of an hour before sunset. Consequently I continued the computations into the following century. In the eclipse of June 14th, 2151, I believe London will be included within the belt of totality, to the southward of the central line.

Eclipses of the Twentieth Century.

The next very large solar eclipse takes place forty years hence, on April 17, 1912. This is a return of that which excited so much interest in 1858. The Moon's semidiameter does not quite equal the Sun's. At London only a narrow crescent on the upper part of the Sun's disk is left uncovered, soon after mid-day. There is another in 1961, but the greatest obscuration seems to take place close upon sunrise. That of 1999 Mr. Hind has shown to be total in the west of England. An eclipse on the morning of April 8th, 1921, is evidently annular in the northern parts of the kingdom, and consequently the next central eclipse we shall have in the British Isles. I have not seen this eclipse anywhere referred to. It will not be so large at London as that of 1912. The only other eclipse of any size occurs on June 30, 1954, but then less than nine-tenths of the Sun's upper limb are obscured at the metropolis about half-past twelve.*

I have expressed the size of each eclipse by the old method of digits, or twelfth parts of the Sun's surface. M. signifies morning, A. afternoon.

Date.	Greatest Obscuration.	Digits Eclipsed.
	h m	
1905, August 30 ..	about 1 4 A.	10
1908, June 28 ..	,, 5 40 A.	2
1912, April 17 ..	,, 0 25 A.	11
1914, August 21 ..	,, 11 57 M.	8
1916, February 3 ..	sets eclipsed.	
1919, November 22 ..	,,	
1920, ,, 10 ..	,,	

* That of 1887 can hardly be regarded, as occurring so near upon the time of sunrise.

There is a large eclipse in 1927, but I doubt its being total or annular anywhere.

Date.			Greatest Obscuration. h m	Digits Eclipsed.
1921, April	8	..	about 8 53 M.	10
1922, March	28	..	,, 2 8 A.	2
1925, January	24	..	,, 3 50 A.	7
1927, June	29	..	,, 5 12 M.	11
1928, November	12	..	,, 8 28 M.	2
1929, ,,	1	..	,, 11 37 M.	1
1936, June	19	..	,, 4 15 M.	6
1939, April	19	..	,, 6 19 A.	4
1942, September	10	..	,, 4 20 A.	4
1945, July	9	..	,, 1 57 A.	7
1949, April	28	..	,, 7 29 M.	4
1952, February	24	..	,, 8 55 M.	1
1954, June	30	..	,, 0 28 A.	10
1959, October	2	..	,, 0 21 M.	4
1961, February	15	..	,, 7 28 M.	11
1966, May	20	..	,, 9 28 M.	6
1968, September	22	..	,, 10 15 M.	4
1971, February	25	..	,, 9 31 M.	7
1972, July	10	..	,, 8 3 A.	6
1973, December	24	..	sets before the middle.	
1975, May	11	..	about 6 29 M.	6
1976, April	29	..	,, 10 17 M.	4
1982, December	15	..	,, 8 16 M.	5
1984, May	30	..	,, 6 13 A.	5
1994, ,,	10	..	,, 6 45 A.	6
1996, October	12	..	,, 2 27 A.	7
1999, August	11	..	,, 10 8 M.	11

Eclipses of the Twenty-first Century.

Those of 2026 and 2081 appear to be total in France. That of 2093 is annular, and probably so at London ; but the central line appears to run a little north of it. That of 2090 I have already alluded to. Column (1) shows date, (2) approximate hour of greatest obscuration, (3) digits, or twelfth part of the Sun's surface eclipsed.

(1)			(2) hour	(3)
2003, May	31	..	rises eclipsed.	
2005, October	3	..	$9\frac{1}{4}$ M.	7
2006, March	29	..	$10\frac{1}{4}$ M.	3
2008, August	1	..	9 M.	2
2011, January	4	..	sunrise	8
2015, March	20	..	$9\frac{1}{2}$ M.	10
2017, August	21	..	7 A.	2

(1)		(2) hour	(3)
2021, June	10 ..	10½ M.	3
2025, March	29 ..	11½ M.	4
2026, August	12 ..	6 A.	11
2027, „	2 ..	9 M.	5
2028, January	25 ..	4¼ A.	7
2030, June	1 ..	5¼ M.	7
2036, August	21 ..	6 A.	8
2037, January	16 ..	8¾ M.	7
2038, July	2 ..	2 A.	1
2039, June	21 ..	6½ A.	9
2048 „	11 ..	1½ A.	9
2050, November	14 ..	2 A.	9
2053, September	12 ..	8¼ M.	7
2059, November	5 ..	8 M.	9
2060, April	30 ..	10¼ M.	2
2066, June	22 ..	8¼ M.	9
2069, April	21 ..	10 M.	4
2075, July	13 ..	4¾ M.	10
2076, November	26 ..	11 M.	5
2079, May	1 ..	11 M.	5
2080, September	13 ..	4¾ A.	9
2081, „	3 ..	7½ M.	11
2082, February	27 ..	4 A.	6
2088, April	21 ..	10½ M.	6
2090, September	23 ..	5½ A.	12
2091, February	18 ..	10 M.	6
2092, „	6 ..	4¼ A.	7
2093, July	23 ..	0¼ A.	11

Eclipses of the Twenty-second Century.

For this century I find four very large eclipses. Those of 2135 and 2200 seem total in England north of London, but in the last instance the Moon's semidiameter does not much exceed the Sun's. The totality of that of 2142 will, I believe, go southward of this country. That of 2151, June 14, attains the greatest obscuration or totality at London, by these tables, about $6^h\ 27^m$. The following are the approximate times of greatest obscuration :—

	hour
2135, October 7	7¾ M.
2142, May 24	8¾ M.
2151, June 14	6½ A.
2200, April 14	5¼ A.

Upton Helions Rectory, Crediton.

*On the Orbit of the Binary Star ξ Ursæ Majoris.**

By Dr. Robert S. Ball.

The object of this paper is to compare some elements which have been computed, with recent observations; to propose a new set of approximate elements; and to give an approximate ephemeris.

The last periastre occurred in 1816·4. Prior to this date the only observations are those of Herschel I. in 1781, 1802, 1804. In the interval of fifteen years from 1804 to 1819 the position-angle swept through 168°, yet no observation has been recorded during this critical period.† The star will reach periastre again in 1876·3, consequently recent observations have to a great extent replaced those wanting between 1804 and 1819.

The four sets of elements here examined are taken from Herschel's *Outlines*, 4th edition, p. 573. Savary's value of the inclination is 59° 40′. By a misprint it is given 50° 40′ in the *Outlines*.

Table I. *ξ Ursæ Majoris.*

Eccentricity. e	Position of Node. Ω	Inclination. γ	Angle between Major Axis and Nodes. λ	Period in Years. P	Perihelion Passage A.D. t	Authority.
0·41640	95° 22′	59° 40′	131° 38′	58·262	1817·25	Savary.
0·37770	97 47	56 6	134 22	60·720	1816·73	Herschel II.
0·41350	98 52	54 56	130 48	61·464	1816·44	Mädler.
0·43148	95 50	52 49	128 57	61·576	1816·86	Villarceaux.

In the comparison of these elements with observation, twenty-two observations have been selected.‡ These observations are distributed as well as possible over the ninety years during which the star has been observed; and whenever a choice has been possible, results of the greatest weight have been taken. The result of the comparison is shown in Table II. (See next page.)

It will be noticed that Savary's elements represent the observations up to No. 6 very well. After No. 6 the calculated position falls behind the observed; the difference reaches a maximum in No. 13, where it amounts to −9°·44. Savary's elements, though the earliest in date, represent the orbit fairly.

The elements given by Herschel II. give for No. 22 a calculated position 17°·43 in excess of the observed position: with this exception, the greatest difference is −6°·06 in No. 13. With reference to this determination, Sir John Herschel remarks, "The case is one highly unfavourable for the application of my method, and, moreover, the resulting elements are those of a first approximation only."

* Read before the Royal Irish Academy.

† At least no such observation is recorded in Mr. Dawes' invaluable list, *M. R. A. S.* vol. xxxv. p. 353.

‡ Many of these observations have been taken from Dawes' list. Others have been supplied by the kindness of Dr. Brünnow.

Table II. ξ *Ursæ Majoris.*

No.	Observer.	Epoch.	Observed Position.	Savary. Calculated Position.	Savary. Diff. from Observed Position.	Herschel II. Calculated Position.	Herschel II. Diff. from Observed Position.	Mädler. Calculated Position.	Mädler. Diff. from Observed Position.	Villarceaux. Calculated Position.	Villarceaux. Diff. from Observed Position.
			°	°	°	°	°	°	°	°	°
1	Herschel I. ..	1781·97	143·78	143·89	+0·11	140·08	− 3·70	142·85	− 0·93	144·12	+ 0·34
2	,, ..	1802·09	97·52	97·40	−0·12	93·92	− 3·60	97·72	+ 0·20	97·73	+ 0·21
3	,, ..	1804·08	92·63	93·07	−0·34	88·52	− 4·11	92·45	− 0·18	92·55	− 0·08
4	Struve ..	1819·10	284·55	284·97	+0·42	285·13	+ 0·58	284·54	− 0·10	285·60	+ 0·05
5	Herschel II. and South	1823·29	258·45	257·45	−1·00	258·37	− 0·08	256·60	− 1·85	254·78	− 3·67
6	South ..	1825·22	244·53	245·50	−0·97	246·45	+ 1·92	244·47	− 0·06	242·38	− 2·15
7	Struve ..	1827·27	228·27	231·50	+3·23	232·68	+ 4·41	230·97	+ 2·70	229·03	− 0·76
8	Dawes ..	1832·27	196·72	191·69	−5·03	195·40	− 1·32	196·39	− 0·33	196·43	− 0·29
9	,, ..	1840·29	150·85	143·65	−7·20	148·92	− 1·93	153·80	+ 2·95	155·48	+ 4·63
10	,, ..	1842·27	144·76	136·50	−8·26	141·48	− 2·28	146·60	+ 1·84	148·33	+ 3·57
11	,, ..	1843·28	142·17	133·29	−8·88	138·15	− 4·02	143·35	+ 1·18	144·98	+ 2·81
12	,, ..	1849·30	126·58	118·44	−8·14	122·27	− 4·31	127·47	+ 0·89	128·58	+ 2·00
13	Miller ..	1852·13	122·28	112·84	−9·44(!)	116·22	− 6·06	121·37	− 0·91	122·22	− 0·06
14	Jacob ..	1853·20	119·47	110·85	−8·62	114·03	− 5·44	119·17	− 0·31	119·93	+ 0·46
15	Dawes ..	1854·36	115·87	108·72	−7·15	111·73	− 4·14	116·85	+ 0·98	117·55	+ 1·68
16	Dembowski ..	1858·20	108·09	101·67	−6·42	104·12	− 3·97	109·29	+ 1·20	109·70	+ 1·61
17	,, ..	1863·23	96·66	90·92	−5·74	92·85	− 3·81	98·54	+ 1·88	98·48	+ 1·82
18	..	1865·12	91·42	85·59	−5·83	87·55	− 3·87	93·67	+ 2·25	94·00	+ 2·58
19	Dembowski ..	1866·30	86·76	81·50	−5·26	83·65	− 3·11	90·20	+ 3·46	90·68	+ 3·92
20	,, ..	1867·31	82·22	77·24	−4·98	79·78	− 2·44	86·82	+ 4·60	87·52	+ 5·30
21	,, ..	1868·30	77·50	72·02	−5·48	75·27	− 2·23	83·02	+ 5·52	84·02	+ 6·52
22	Brünnow ..	1872·28	24·19	20·57	−3·62	41·62	+17·43(!)	57·19	+33·00(!)	62·10	+37·91(!)

Mädler's elements represent the first eighteen observations with surprising fidelity, and there is no very serious discrepancy until No. 22, when the difference is 33°.

Villarceaux's elements give for No. 22 a discrepancy of 37°·91.

There cannot be a doubt that, had the four eminent astronomers who have been mentioned had the advantage of several observations in the neighbourhood of periastre, their orbits would have been verified by the recent observations. Three of the orbits, Savary's being the exception, appear to have too large a value for the periodic time. This is the principal source of the discrepancies. In the absence of Mr. Brünnow's observation No. 22, and some others preceding it, Mädler's elements would have fair claims, but it will be evident that some change is rendered necessary by the recent observations.

By the aid of Sir John Herschel's beautiful graphic process, *M. R. A. S.* (vol. v. p. 209), the following approximate elements have been determined:—

$$\begin{aligned} \Omega &= 103°{\cdot}6 \\ \gamma &= 53{\cdot}1 \\ \lambda &= 135{\cdot}3 \\ P &= 59{\cdot}88 \\ \varepsilon &= 1816{\cdot}405 \end{aligned}$$

These elements have been compared with the twenty-two observations already mentioned, and also with two more, Nos. 22 and 23 of the following Table:—

Table III. *ξ Ursæ Majoris.*

Comparison of the new Approximate Elements,

No.	Authority.	Epoch.	θ_c the Observed Angle of Position.	θ_c the Computed Angle of Position.	Difference $\theta_c - \theta_c$
			°	°	°
1	Herschel I. ..	1781·97	143·78	147·37	+3·59
2	,, ..	1802·09	97·52	98·53	+1·01
3	,, ..	1804·08	92·63	92·55	−0·08
4	Struve ..	1819·10	284·55	287·93	+3·38
5	Herschel II. and South	1823·29	258·45	259·20	+0·75
6	South ..	1825·22	244·53	246·20	+1·67
7	Struve ..	1827·27	228·27	231·63	+3·36
8	Dawes ..	1832·27	196·72	195·13	−1·59
9	,, ..	1840·29	150·85	152·95	+1·10
10	,, ..	1842·27	144·76	145·98	+1·22
11	,, ..	1843·28	142·17	142·85	+0·68
12	,, ..	1849·30	126·58	127·10	+0·52
13	Miller ..	1852·13	122·28	120·87	−1·41

No.	Authority.	Epoch.	θ_o the Observed Angle of Position.	θ_c the Computed Angle of Position.	Difference. $\theta_c - \theta_o$
			°	°	
14	Jacob ..	1853·20	119·47	118·58	−0·89
15	Dawes ..	1854·36	115·87	116·12	+0·25
16	Dembowski ..	1858·20	108·09	107·80	−0·29
17	,, ..	1863·23	96·66	94·87	−1·79
18	..	1865·12	91·42	88·43	−2·99
19	Dembowski ..	1866·30	86·76	83·52	−3·24
20	,, ..	1867·31	82·22	78·55	−3·67
21	,, ..	1868·30	77·50	72·58	−4·92(!)
22	,, ..	1870·24	57·74	56·10	−1·64
23	,, ..	1871·22	47·70	43·80	−3·90
24	Brünnow ..	1872·28	24·19	26·47	+2·28

The greatest discrepancy is in No. 21, where the difference amounts to $-4^{\circ}\cdot92$.

The angle of position is at present changing at the rate of nearly 20° per annum, consequently observations during the next few years will be of the greatest service in sidereal dynamics.

From the approximate elements which have been given the following approximate ephemeris has been computed A comparison of the positions given in this ephemeris with observations may perhaps provide materials for the final correction of the elements. The angle of position is computed at intervals of three months from 1872·50 up to 1878·75. The star will pass periastre in 1876·28.

Table IV. Approximate Ephemeris of the Angle of Position of *ξ Ursæ Majoris.*

No.	Epoch.	Angle of Position.	No.	Epoch.	Angle of Position.
		°			°
1	1872·50	22·4	14	1875·75	321·4
2	·75	17·5	15	1876·00	317·9
3	1873·00	12·5	16	·25	314·7
4	·25	7·3	17	·50	311·6
5	·50	2·2	18	·75	308·6
6	·75	357·2	19	1877·00	305·8
7	1874·00	352·1	20	·25	303·2
8	·25	347·0	21	·50	300·7
9	·50	342·2	22	·75	298·4
10	·75	337·6	23	1878·00	296·1
11	1875·00	333·2	24	·25	293·9
12	·25	329·0	25	·50	291·8
13	·50	325·1	26	·75	289·7

Essay on the Arc of the Meridian measured in Lapland. By I. Todhunter, M.A., F.R.S. *Transactions of the Cambridge Philosophical Society*, vol. xii. part I.

In this essay, Mr. Todhunter gives a series of valuable and interesting critical remarks on the accounts which have been given of the two measurements of the celebrated Lapland arc. He points out many (and some most remarkable) errors in these accounts, and applies the appropriate corrections.

It would be altogether impossible to give an abstract of the essay, which is already singularly condensed. Every line should be carefully studied by those who desire to know the real history of the important operations in question.

The following reflections are instructive and suggestive:—

"It would be a curious subject of speculation whether the theoretical opinions of persons engaged in geodetical surveys could have exercised any influence on their observations; I mean of course unconsciously, for it would be wrong to suspect any deliberate unfairness in any of the operations which I have examined. From a passage in the article *Figure de la Terre* by D'Alembert, in the original *Encyclopédie* it would appear that the school of Cassini originally believed that in consequence of the oblate form of the Earth, the length of a degree of the meridian *would decrease* from the equator to the pole. It seems strange, perhaps, now to suppose that such an error could be seriously maintained; but there can be no doubt of it: for example, the error was vehemently maintained by Keill, a man of some reputation, who was ultimately a Savilian professor at Oxford. See Keill's *Examination of Dr. Burnet's Theory of the Earth*, p. 140. It is certainly a remarkable coincidence that the school of Cassini, starting with the erroneous theoretical notion that the degrees of the meridian *ought* to decrease from the equator to the pole, arrived at the same result by observation and measurement. There can, I think, be no doubt that at least Maupertuis and Clairaut, who were the most eminent of the French party, held the correct Newtonian theory as to the figure of the Earth; and their result was rather too decided in its confirmation of this theory. Now the geodetical angles could scarcely be influenced by the theoretical opinions of the observers; because it would not be obvious in what way the result would be affected by an error in an angle. But in measuring the base it would of course be obvious that the larger was the value obtained, the stronger was the evidence for an oblate form. Similarly in estimating the amplitude, the smaller the value obtained the stronger was the evidence for the oblate form. In these two parts of the survey then it would be necessary to be on the watch lest the conviction of what the result ought to be should influence the impression of what the observation really gives. It is curious that Maupertuis and his party seem to have thought at first that

their success was too decided and therefore their amplitude too small; and that on their second determination they should have made it between 3″ and 4″ larger than at first. Svanberg, I consider, was sent to Lapland with a strong expectation that he would obtain a less value of a degree of the meridian than that of Maupertuis. See Melanderhjelm's preface to Svanberg's book."

Mr. Todhunter makes the following remarks on a question of mathematical history:—

"Svanberg alludes to the researches of Huygens on centrifugal force; and then he says that if we suppose with Huygens that the force of gravity resides in the centre of the Earth we obtain for the ellipticity $\frac{1}{578{\cdot}73}$. Then he proceeds with the strange statement that these discoveries were the precursors of the hypothesis which Newton afterwards proposed of universal gravitation. Thus Svanberg ascribes to Huygens and not to Newton the priority in investigations of the figure of the Earth. Now the first edition of the *Principia* was published in 1686. Huygens published in 1690 his *Discours de la cause de la Pesanteur*. Although it appears from the preface that some part of this work had been long before communicated to the Academy at Paris, yet Huygens excepts the part which relates to the motion of pendulums as affected by the figure of the Earth: and all that relates to the calculation of the figure of the Earth he expressly says was added after the publication of Newton's *Principia*. Perhaps Svanberg was misled by a hasty glance at Bailly's *Histoire de l'Astronomie Moderne*, vol. iii. p. 9. Bailly accidentally notices Huygens before Newton. Again Svanberg says, 'Newton ne tarda pas à remarquer, que l'hypothèse de Huygens d'une force unique tendante au centre de la terre, étoit équivalente à celle d'y supposer une densité infinie.' I do not know what this means. Huygens really used the hypothesis of a force constant in magnitude, and directed always to the centre of the Earth; it is of course only as to the latter part of the hypothesis that we can assert the equivalence of an infinite density at the centre. I do not think that Newton drew attention to this equivalence: Clairaut did in the *Philosophical Transactions*, vol. xl. pp. 277–306. Clairaut, I think, was the first who showed that Huygens' value of the ellipticity follows approximately from the latter part of Huygens' hypothesis, namely, that the force always passes through the centre, without assuming any particular law of intensity of the force at different distances. See Clairaut's *Figure de la Terre*, p. 141. See also Plana, *Astronomische Nachrichten*, No. 839."

The Orbit of Castor. By J. M. Wilson, Esq.

In the last number of the *Monthly Notices* I stated that the result of an examination of the orbit of *Castor* by graphical

methods was that it was hyperbolic. These methods are rough, and in this case present peculiar difficulties. Since writing that note, I have attacked the question analytically, following the method of Sir John Herschel, in *Mem. Ast. Soc.* Vol. xviii., and have the pleasure to acknowledge much help in the arithmetical part of the work from my friend Mr. Henry Stevenson, of Bedford, who undertook the laborious task of solving the equations.

The method is as follows: The polar co-ordinates, r, θ, of the determined points are converted into rectangular co-ordinates, x, y. An equation is then assumed to a conic section, which passes through these points,

$$0 = 1 + \alpha x + \beta y + \gamma x^2 + \delta x y + \varepsilon y^2,$$

and by substituting the values of x, y for the points determined, as many equations are found for α, β, γ, δ and ε as there are points. These are combined by the method of least squares, so as to give the most probable result. I omitted the point corresponding to 1740·46 as resting on very insufficient evidence; and I am inclined to believe that a still better result would be obtained if the next two points were also omitted, or had much less weight assigned them.

By a singular coincidence, in the solution of the equation, the coefficients of x^2 and y^2 come out so small as not to affect the first seven places of decimals, and hence the curve is seen at once to be approximately a rectangular hyperbola, whose asymptotes are parallel to the axes, and whose eccentricity is 1·414.

The resulting equation is

$$0 = 1 + \cdot 008876x + \cdot 008098\,y + \cdot 0000433\,x\,y,$$

A being the origin and the positive parts of the axes of x and y, being in the directions 90° and 180° measured in the usual manner from the north.

The eccentricity of the real orbit may hence be approximately computed at 1·625.

The divergence of this result from that obtained by graphical construction is at first sight very great, for by that the eccentricity of the apparent orbit was more than 2. But the graphical solution is not to be trusted, and in this case it is easy to make errors that prejudicially affect the eccentricity. One of my pupils—Mr. D. C. Baynes—made the curve nearly parabolic on one occasion, and on another he made the eccentricity 2·01. An error of a tenth or twentieth of an inch in measurement, or a corresponding error in drawing the hyperbola, would vitiate the result completely. To determine the centre and axes of an incorrectly drawn hyperbolic arc in the neighbourhood of the vertex is a very unsatisfactory problem. The analytically obtained result has more weight: that is, it has the weight, to the degree of approximation to which it has been carried, of that combination of the original observations which is given by the interpolating curve, smoothed by the method of differences to the third order, with no errors of drawing superadded.

I have here a chart* showing all the observations that have been sent me, from which it can be judged how far the interpolating curve adopted is a fair representation of them; and a roughly drawn chart marking the positions of the stars at different dates, and the supposed hyperbolic arc on which they lie. The deviation of the curve from the early positions is great, but they rest on very few observations, as is seen from the other chart, and several of the early observations, as of the late ones, are many degrees in error.

It occurred to Mr. Seabroke and myself that it would be worth while to examine the spectra of A and B, to see whether the indication derived from the orbit, that they belonged to different systems, was confirmed; but the long delay of an optician in preparing part of the necessary apparatus has frustrated us for the present.

There appears to be something peculiar about the motion of this pair. Every successive determination of the eccentricity of the relative orbit has increased that eccentricity, as shown by Mr. Proctor in his note on my former paper. It may be thought worth while, by some one with more skill or more leisure than I possess, to subject the orbit to a searching examination, and this is my object in bringing the matter in a confessedly unfinished state before the Society.

My own conclusion is, that it is now probable that the orbit is really hyperbolic.† If so, *Castor* must be looked on, not as a binary system, but as two stars, whose relative proper motions have been in nearly opposite directions, and whose near approach has been witnessed once, and will never be witnessed again.

Temple Observatory,
Rugby, June 14, 1872.

On the Desirability of Watching for the November Meteors in the present year. By Rich. A. Proctor, B.A. (Cambridge.)

On the night of November 13–14, 1871, no members of the November meteor system were observed in England; and the conclusion was arrived at that the richer portion of the system has passed so completely beyond the Earth's orbit that no displays may be expected until the close of the century. Mr. Glaisher, in fact, promised his meteor-observing assistants at Greenwich that they should no longer be kept on the watch after midnight on November 13-14. There are reasons for believing, however, that the conclusion on which this promise was based is incorrect. What appears to have happened is simply this, that a more expanded portion of the meteor stream is now traversing the Earth's orbit, and that accordingly the passage of the Earth through the system

* The publication of this chart is unavoidably delayed.

† My friend and former pupil, Mr. A. M. Worthington, of Trinity College, Oxford, has worked the whole question over again from the original data, and makes the orbit a hyperbola of small eccentricity, *i e.* nearly parabolic.

lasts longer than in former years, while, owing to the irregular constitution of the system, several successive hours may pass without any meteors being seen.

For, although the night of November 13-14, was not attended (in England and France at least) with any display of the Leonides, yet on the night of November 14-15, many meteors were seen at certain stations where the weather was favourable. Thus, at Alexandria, Prof. Parnisetti, and five assistants, obtained the following results :—

Between	10	and	11 P.M.,	Nov. 14,	3	meteors were counted.
	11	„	12	„	6	„
	12	„	1 A.M.,	„ 15,	19	„
	1	„	2	„	23	„
	2	„	3	„	84	„
	3	„	4	„	100	„
	4	„	5	„	95	„
					300	

As the sky was not at any time quite clear, this result shows that between 2 and 5 a veritable meteoric display was in progress.

At Volpeglino, near Tortona, Signor Maggi observed 52 meteors (most of them Leonides) between 3.15 and 6.15 A.M. The sky was much clouded, however.

At Genoa, Professor Garibaldi counted more than 100 meteors between 8.15 P.M. Nov. 14, and 1.30 A.M. Nov. 15.

It is even more deserving of notice, however, that at Moncalieri on the night of November 16-17, no less than 128 meteors were counted, of which the majority were Leonides. The significance of this observation will be understood when it is remembered that the Earth had traversed nearly 3 millions of miles between the epochs of the observations made at Alexandria and Moncalieri.

It may be added that in 1870 Capt. Tupman had noticed that Leonides began to fall in considerable numbers two or three days before November 13-14.

It would appear that instead of discontinuing the observations altogether, what is now wanted is that a watch should be maintained during the hours between 10 P.M. and 6 A.M. (say) from November 10 to November 17. I fear this suggestion is not likely to be unanimously welcomed.

Prof. Denza remarks of the passage last year, that 'the meteor-cloud has appeared not only to be less dense, but displaced from its usual position, very turbid (*troublé*) and irregular; for the portion which the Earth traverses at present is but a remnant, and, as it were, a tenuous tail behind the more densely crowded central group.' 'It is to be inferred, also,' he adds, 'that the flight of meteors is extending itself gradually along its orbit,—a process which will in the long run cause the whole orbit to be occupied by cosmical matter, after which there will be displays of the meteors not merely at intervals of $33\frac{1}{4}$ years, but year after

year, and with about the same degree of richness, precisely as in the case of the August meteors, or Perseides, whence we can understand the great interest attaching to the study of these objects during the next few years, for the purpose of tracing the law according to which the progressive diminution of these displays proceeds, especially if we remember (as Prof. Schiaparelli, of Milan, has pointed out to me), that a fine shower was observed in 1818, that is to say, nearly midway between the great displays of 1799 and 1833.'

A General Comparative Table of Radiant-Positions and Duration of Meteor-Showers. By R. P. Greg, Esq., F.R.A.S.

The accompanying Table of Radiant-Positions and Epochs of Meteor-Showers is intended to show at a glance the comparative results of all the meteoric showers whose centres of radiation, in right ascension and north declination, and whose epochs have hitherto been approximately or definitely ascertained. The recent increased interest attached to meteoric science since Professor Schiaparelli's discovery of the intimate connexion between the orbits of comets and meteor-rings renders it most desirable that the scattered and laborious researches of various observers and collators should be brought together and synoptically arranged. This I have endeavoured to do in as brief and simple a manner as possible. Having due regard to the nature of the case, there results a greater amount of coincidence and resemblance than might have been expected from the reductions of nearly 6000 observations, independently of Leonides and Perseides, made by different observers in different countries, recorded during the last twenty years. Indeed the results are frequently remarkably coincident, when we consider how difficult it is to arrive, even in the case of the more frequently observed and better known Leonides and Perseides, at a precise radiant-point. It is even less simple to ascertain with anything like precision the extent and configuration of the radiant area when, as is frequently the case, it more or less diffusely occupies a region amongst the stars of some 10° or 20° in diameter. In some cases it is highly probable that the area is simply "diffuse;" in others it probably includes a series of minor or sub-radiants (the existence and origin of which have been ingeniously, and perhaps correctly, explained by Signor Schiaparelli*), and of whose existence I had myself expressed a suspicion, some years ago, in the Report of the British Association for 1868–9. The probability of the existence, also, of meteoric showers having a duration of some six weeks appears to be still further confirmed by the comparative table or catalogue now presented. (See *Proceedings of the British Meteorological Society* for January 1865.) Professor Heis (see the *Astronomische Nachrichten*, April 1867) was the first systematically to attempt to group and arrange centres of

* See the Report of the British Association Committee on Luminous Meteors, 1871.

radiation for meteor-showers, as deduced from a series of many hundreds of observations recorded and mapped by himself and pupils at Münster, in Westphalia; but he did not attempt to fix the exact duration, or radiant-position, of individual meteor-showers, or the relative importance of the different meteoric systems. Messrs. Greg and Herschel attempted to do this more systematically, both from special observation and by a reduction of some 2000 meteors recorded in the annual Meteor Reports and Catalogues of the British Association (see the vols. of the British Association Reports for 1864, and 1868–70). The results were also laid down in a series of 22 folio plates upon an atlas of the stars gnomonically projected. In addition, a number of new radiants were also determined by myself, deduced from some 700 Italian observations observed and described by Signors Zezioli, Denza, and Serpieri, during the years 1868–1870; and many of the English ones were found to be fairly well confirmed by the Italian observations. The catalogue of meteor-radiants lately published by Schiaparelli, chiefly and specially deduced from some 900 (out of nearly 7000) observations made in the course of three years, 1867–1869, by the late indefatigable observer Signor Zezioli, of Bergamo, was drawn up with the more special view of tracing out the specific centres of radiation of various separate or identical meteor-showers, and their possible daily alterations of position. The result seems frequently to confirm a number of the radiants of Professor Heis and of Messrs. Greg and Herschel, and to indicate more clearly the probable occurrence of subordinate or multiple radiant-points belonging to one and the same meteor-system. (See the British Association Reports, 1871, p. 44, *et seq.*) It may also be here noted that the Italian observations, generally more consecutively and regularly conducted, include, necessarily, a far larger proportion of small meteors, of 4th and 5th magnitudes, than could be the case with the English and German ones; and also that, though including a greater number of probable meteor-showers of minor and secondary importance, these nevertheless possess features of much scientific interest. Probably the catalogue of radiants given by Messrs. Greg and Herschel show best the general positions, epochs, and durations of the more prominent showers; but much has yet to be done, doubtless, in more precisely and accurately determining those features. The very considerable number of centres of radiation, combined with the frequent, and evident tendency to width and diffuseness in some of the radiant areas themselves, combine to make the reductions and grouping of the paths, or meteor-tracks, for any single radiant, on celestial maps especially constructed for the purpose, often a matter of considerable complexity and difficulty. Mr. Greg thought at first that there was a not unfrequent tendency, in long-enduring showers, to give a radiant advancing with the time among the stars; but though, undoubtedly, the radiant area frequently appears to have an elongated form, further investigation does not seem to bear out that idea. Possibly the radiants M 6, 7, M 7, 8, S 5, 6, 7, 8, however, are exceptions. Signs of elongation of the radiant area

are considered by Mr. Greg, Signor Serpieri, and Professor Newton to be more or less plainly noticeable in the principal meteor-showers of August, November, and December. Some short-lived showers, or those having days of special maximum, as K 1, 3, O, L (the November shower), and Q H 2, however, appear to have a very fairly precise centre of radiation. The radiant points by Prof. Schiaparelli are those given by Dr. G. von Boguslawski, of Stettin, in his recent German publication of a new edition (considerably enlarged by the author), of Schiaparelli's work on the *Astronomical Theory of Shooting Stars*. The 189 radiants there given are, in this Table of Comparisons, reduced by grouping to 79, and the grand total of the radiants now presented is 132. It is, however, probable that a certain number of these are either pseudo-centres or require further confirmation or correction. In some cases, probably, the truest radiant-positions may be found in a more or less nearly average position of those given by two or three of the catalogues now for the first time fully and systematically tabulated and arranged together. In several cases, as with U, B 5, R G, E 2, Y, H, of Greg and Herschel, some of them representing very well-marked and important meteor-showers, the position and epoch given by Greg and Herschel are certainly more accurately placed and determined than those of their counterparts in the other lists. For certain showers, as L, A 10, Q H 1, V, T 1, Q H 2, O, G 1, K 1, 3, A G 1, S 4, S G 2, U, F 1, 2, L H, &c., there are pretty well established days of maximum frequency, giving meteors more or less characteristically distinguished from those of other showers. Some of these distinctions or peculiarities have been attempted to be given with the Atlas published by Messrs. Greg and Herschel for the British Association in 1868, but more observation specially directed to these points is required. It is yet too early to attempt to give results of a comparison of the list of radiant-points with the orbits of comets; but it is well known that some successful attempts in this direction have been already made by Schiaparelli, Weiss, Galle, Newton, and D'Arrest. The first and most important object at present attempted to be gained is to collect all the best observed radiant-positions and epochs of the meteoric showers themselves, and to ascertain, by special and further observation, with as much accuracy as possible, their true positions and durations. With the view to assist these determinations, and to enable observers to arrive at uniformity in the method and arrangement of their results, it is hoped that the accompanying Table will be found to be of some utility, as representing, principally for the northern hemisphere, the limits to which this branch of observations in meteoric astronomy may be briefly and comprehensively described as having at present reached. In most cases positive accuracy is impossible, from the very nature of the case, absolute accuracy of observation of the meteors themselves being unattainable; nor, in many cases, is it probable that the exact average centre of radiation of a number of meteors will be quite similarly determined by two different collators, even from the same series of observations.

A Synoptic or General Table of the Radiant Positions and Duration of Meteor Showers, observed in the Northern Hemisphere, 1872.

Progressive No. 1872, (R. P. Greg).	Epoch or Duration of Meteoric Shower.	Average Position of Radiant. R.A.	Average Position of Radiant. N.D.	Name or Number of Radiant.	Authority.*	Observations. (N.B. Radiant Area supposed to be 15° in Diameter. Radiants, "Z," by Mr. Greg, from Zezioli's Observations.)
1	Dec. 20 — Feb. 26	10°	86°	N G	G. & H.	Radiant elongated 20°, +88° to 320°, +80°. Centre 350°, +87°?
	Dec. 15 — Feb. 14	222	87	N 21, 1, 2, 3	Heis	
2	Dec. 27 — Jan. 31	130	47	189, 7, 23	S. & Z.	Centre about 135°, +45° = Comet of 1680? (Weiss).
	Jan. 1 — Feb. 9	135	40	M 1, 2	G. & H.	
	Jan. 1-15	145	51	M 1	Heis	
3	Dec. 27 — Jan. 29	203	53	1, 6, 12, 13, 16, 18, 21, 188	S. & Z.	Radiant multiple.
	Jan. 6-29	200	55	Z 10	G. & H.	
4	Jan. 2-3	238	45	K 1, 3	G. & H.	Corroborated by American observations. A notable meteor epoch, maximum 2nd-3rd Jan.
	Dec. 15 — Jan. 15	231	53	K 1, 3	Heis	
5	Jan. 10	10	57	3	S. & Z.	Probable centre near 22°, +56°.
	Dec. 20 — Jan. 30	21	56	A 1, 2	G. & H.	
	Dec. 15 — Jan. 31	32	56	A 20, 1, 2	Heis	
6	Jan. 11	47	40	4	S. & Z.	
7	Jan. 6	150	67	G_2	G. & H.	(Noticed by Mr. Clark, at York, 1872.) Possibly = No. 132.
8	Dec. 22 — Feb. 6?	181	35	2, 5, 30, 185, 186	S. & Z.	Radiant area large; multiple; real centre at 180°+35° = Comet II. 1792? (Weiss). Heis probably incorrect.
	Jan. 1-25	183	36	M G 1	G. & H.	
	Jan. 16 — Feb. 1	169	45	M 2	Heis	
9	Jan. 19 — Feb. 5	209	25	9, 14, 15, 27	S. & Z.	Radiant multiple?
10	Jan. 27	132	67	17	S. & Z.	Centre about 140°, +70°?; diffuse, and rather uncertain.
	Jan. 21 — Mar. 20?	140	71	M 4, 5	G. & H.	
11	Jan. 28	67	25	19	S. & Z.	Denza found 72°, +18°.
	Dec. 20? — Feb. 6	65	20	A G 1	G. & H.	
12	Jan. 3 — Mar 16	143	−7	S 1, S G 1	G. & H.	
13	Jan. 9-19	72	4	G_3	G. & H.	Reduced from Denza's obs. 1868, by Mr Greg, and confirmed in England.
14	Jan. 19 — Feb. 6	242	63	11, 29	S. & Z.	(223°, +54°, by Mr. Greg, from Denza's observations.) Centre 225°, +54°.
	Jan. 29 — Feb. 6	223	54	K 2	G. & H.	
	Jan. 15-31	227	54	K 2	Heis	

The initials S. & Z., refer to Prof. Schiaparelli and Sig. Zezioli (1867–1870); G. & H., to Mr. Greg and Prof. Alex. Herschel (British Association, 1848–1871); Heis, to Prof. Heis, of Münster (1839–1867). The Nos. under "Name or Number of Radiant," to Boguslawski's Catalogue in the translation into German of Signor Schiaparelli's work on meteors.

Epoch or Duration of Meteoric Shower.	Average Position of Radiant. R.A. °	N.D. °	Name or Number of Radiant.	Authority.	Observations. (N.B. Radiant Area supposed to be 15° in Diameter. Radiants, "Z," by Mr. Greg, from Zezioli's Observations.)
Jan. 18 — Feb. 13	226	30	8, 10, 20, 22, 24, 25 ?, 33	S. & Z.	Radiant multiple; centre 230°, + 32°.
Jan. 28-29	233	34	Q Z	G. & H.	
Feb. 1-14	61	46	A 3	Heis	
Feb. 6	183	56	31	S. & Z.	Probable commencement of M 7 of Heis.
Feb. 1-28	172	59	M 3, 4	Heis	
Feb. 16	74	48	39	S. & Z.	= A Z 3; centre 73°, + 40°. Radiant precise.
Feb. 9-17	73	40	A 3, 4	G. & H.	
Feb. 15-28	76	40	A 4	Heis	
Feb. 6-15	131	52	28, 37	S. & Z.	Requires further investigation. Radiant elongated according to Schiaparelli.
Mar. 1-15	120	54	M 5 ?	Heis	
Mar. 1-15	50	47	A 5	G. & H.	Confirmed by Italian obs.
Feb. 1 — Mar. 15	50	49	A 5	Heis	
Feb. 3	153	21	26	S. & Z.	
Feb. 4-26	153	35	M 3	G. & H.	
Feb. 10 — Apr. 2	175	10	S 2, 3	G. & H.	This series of radiants (S. of Heis) seen by Neumayer in Australia, probably advances from R.A. 175 to R.A. 200, with the time.
Feb. 15 — Mar. 31	177	13	S 1, 2, 3	Heis	
Feb. 11-20	194	15	S 2, a	G. & H.	Possibly a continuation of No. 14.
Feb. 17-19	238	51	40, 41	S. & Z.	Meteors small.
Feb. 13	133	26	32	S. & Z.	Ditto.
Feb. 14	105	62	34	S. & Z.	Ditto.
Feb. 14	263	68	36	S. & Z.	Ditto.
Feb. 15-28	245	76	N 4 ?	Heis	
Feb. 14-15	209	52	35, 38	S. & Z.	Ditto.
Mar. 1-15	50	49	A 5 ?	Heis	
Mar. 3-25	247	− 3	S Z 1	G. & H.	Possibly commencement of S Z 2.
Mar. 5-17	190	1	S 4	G. & H.	Probable commencement of S 5, 6.
Mar. 9-27	74–112	32–47	A Z 1, 2, 3	G. & H.	In part = A 3, 4 radiant contd. ? Small meteors obsd. by Zezioli: A Z 1 = 112°, +32° A Z 2 = 98°, +46 A Z 3 = 74°, +47 = A 3, 4 ?
Mar. 20 — Apr. 25	143	51	43, 61	S. & Z.	Central position 148, + 48; perhaps connected with M Z.
Mar. 22 — Apr. 23	146	46	M Z	G. & H.	
Mar. 16-31	150	47	M 6	Heis	
Mar. 17	186	56	42 ?	S. & Z.	Probable continuation of M 3, 4 of Heis. Centre 180, + 50.
Mar. 3 — Apr. 30	180	60	M 6, 7	G. & H.	
Apr. 1-15	180	49	M 7	Heis	

Progressive No. 1872, (R. P. Greg.)	Epoch or Duration of Meteoric Showers.	Average Position of Radiant. R.A.	Average Position of Radiant. N.D.	Name or Number of Radiant.	Authority.	Observations. (N.B. Radiant Area supposed to be 15° in Diameter. Radiants, "Z," by Mr. Greg, from Zezioli's Observations.)
		°	°			
35 (50)	Apr. 1-23	256	43	46, 49, 50, 51, 57, 60	S. & Z.	Multiple radiant. Possibly commencement of D G 2. General centre of D G 1, D G 2 = 268, +51? (See No. 50).
	Mar. 11 — Apr. 23	267	53	D G 1	G. & H.	
36	Mar. 27 — Apr. 30	224	38	44, 48, 54, 65	S. & Z.	
	Mar. 12 — Apr. 30	223	40	M G 2	G. & H.	
37	Mar. 15 — Apr. 20	305	27	W Z	G. & H.	
38	Apr. 25	260	24	63	S. & Z.	Prof. Herschel, 13 April, 1864, = 273°, + 25½° = Comet I. 1861? (Weiss). Max. 13th April. R. P. Greg, 20th April, 1872, 267° + 25°
	Mar. 15?—Apr. 23	268	25	Q H 1	G. & H.	
39	Mar. 19?—Apr. 22	277½	34½	Q H 2	G. & H.	Prof. Serpieri (267°, + 35°). Prof. Galle (278°, + 34½°) = Comet I. 1861? (Weiss and Galle) A notable shower; max. display April 19–22. Q H 1, Q H 2 and C, probably all identical.
	Apr. (20) 15-31	277	38	C	Heis	
40	Mar. 20 — May 29	227	−5	S G 2 (S Z 2)	G. & H.	
41	Mar. 25 — Apr. 30	290	−10	O Z	G. & H.	More observations required.
42	Apr. 11-29	187	24	53, 64	S. & Z.	
	Mar. 25 — Apr. 24	198	32	M G Z	G. & H.	
	Apr. 1-30	192	18	S 4, 5	Heis	
43	Mar. 30 — Apr. 14	210	54	45, 47, 55, 59	S. & Z.	Prof. Serpieri, 1869 (202 + 62). This radiant appears to advance with the time, and is a continuation of M 6, 7; lasting ten weeks?
	Apr. 25 — May 25	202	52	M 7, 8?, M 6, 7 continued	G. & H.	
44	Apr. 10-14	165	47	52, 56	S. & Z.	
	Apr. 15-30	160	49	M 8	Heis	
45	Apr. 14	240	55	58	S. & Z.	
46	Apr. 25	256	75	62	S. & Z.	
	Apr. 10 — May 4	70	87	N 8?	G. & H.	Radiant, well defined near *Polaris*.
	Apr. 1-30	267	84	N 7, 8	Heis	
47 (31)	Apr. 2 — May 4	194	9	S 5, 6	G. & H.	Radiant elongated, 189° to 200°, R. A.; and 5° to 12° Dec. = S. 5, 6, 8?
48	Apr. 29 — June 12	123	40	M G 4	G. & H.	
49 (53)	Apr. 19-20	152	22	M 3 Z	G. & H.	(Perhaps commencement of Y?) Elongated radiant?
50 (35)	May 25	280	54	74	S. & Z.	Well-defined radiant and shower; continuation of D G 1 possibly.
	Apr. 23 — May 31	270	55	D G 2	G. & H.	
51	May 22 — July 5	240	24	70, 83, 87	S. & Z.	A well-marked shower. Radiant centre at 239° + 23°, and probably multiple. Duration nine weeks. β *Herculis* in April; and possibly distinct from position in corona for June.
	Apr. 12 — June 30	240	25	Q 1, 2	G. & H.	
	May 1 — June 30	237	19	Q 1, 2	Heis	
52	Apr. 27 — June 30	305	81	N 9, 10	G. & H.	Radiant well defined.
	May 1-31	236	81	N 9, 10	Heis	

No. 1872 (R. P. Greg).	Epoch or Duration of Meteoric Shower.	Average Position of Radiant. R.A. °	N.D. °	Name or Number of Radiant.	Authority.	Observations. (N.B. Radiant Area supposed to be 15° in Diameter. Radiants, "Z," by Mr. Greg, from Zezioli's Observations.)
(49)	Apr. 29 — May 15	163	12	Y	G. & H.	(= M 3, Z ?) Radiant elongated, 160° to 167° R.A., and 75° to 70° Dec.
(47)	Apr. 2 — May 4	195	7	S 5, 6, 8	G. & H.	Probably a continuation of S 4, 5.
	May 1-31	202	9	S 6	Heis	Radiant elongated?
(62)	May 1-31	325	55	B 1	Heis	Probably commencement of No. 62 or 65.
6	May 18 — June 14	273	34	68 (?), 75, 79	S. & Z.	Radiant elongated? centre at 270°+32 (No. 68 doubtful.)
	May 6 — June 30	280	29	W	G. & H.	
7	May 2 — June 20	312	21	W G	G. & H.	Radiant elongated.
	June 28	302	27	82 ?	S. & Z.	
8	May 2 — June 9	206	39	66, 72, 78	S. & Z.	Small meteors; probably a multiple radiant.
9	May 16 — June 2	235	43	67, 71, 77	S. & Z.	Ditto.
0	May 22-24	301	37	69, 73	S. & Z.	Ditto.
1	May 26	237	59	76	S. & Z.	Ditto.
(55)	June 1-30	333	42	B 2	Heis	(= B 1 of Heis continued?) Doubtful.
3	June 7 — Aug. 12?	294	3	Q G	G. & H.	=Neumayer and Heis ♓ radiant? Radiant, well defined at 294°+7°.
	June 1-30	292	15	W	Heis	♓ 2 for July at 305 + 5.
4	June 1-29	168	55	M G 3	G. & H.	Radiant rather uncertain, more observations needed.
5	July 18-31	320	62	94 ?, 101, 102, 107, 114 ?, 127	S. & Z.	Multiple radiant. Radiant precise.
	June 11 — July 11	315	60	B 1	G. & H.	
	July 1-31	317	62	B 3, 4	Heis	
6	June 28 — Aug. 3	270	51	81, 90, 95, 97, 121, 131	S. & Z.	Confirmed in 1872 by Miss Herschel at 274°, + 57°.
7	June 29 — Aug. 24	330–345	14	T 1	G. & H.	Requires further investigation; and possible connexion with Nos. 76 and 88. At 345 + 15 in 1871, A. S Herschel. Radiant elongated.
(80)	June 19?—Aug. 4	304	40	80 ?, 86, 88, 92, 109 ?, 112, 116, 117, 120, 126, 133	S. & Z.	
	July 10 — Aug. 20	310	47	B 4	G. & H.	Heis B. 6, doubtful. Clark at York gives the position at 315°, + 42°.
	Aug. 15-31	304	59	B 6?	Heis	
9	July 4	3	68	84	S. & Z.	Radiant diffuse; elongated?
	July 7 — Aug. 4	12	70	N 11	G. & H.	
0	July 5	222	60	85	S. & Z.	Serpieri; 11 July, 1868 = 200°, +55°, centre 216°, + 57°? Confirmed by Zezioli's observations.
	July 1-11?	210	55	M G 5	G. & H.	
1	July 2 — Aug. 16?	280	65	B 3	G. & H.	Heis, position doubtful.
	July 8	288	64	89	S. & Z.	
	Aug. 1-15	297	68	B 5	Heis	

Progressive No. 1872, (R. P. Greg).	Epoch or Duration of Meteoric Shower.	Average Position of Radiant. R.A.	N.D.	Name or Number of Radiant.	Authority.	Observations. (N.B. Radiant Area supposed to be 15° in Diameter. Radiants, "Z," by Mr. Greg, from Zezioli's Observations).
		°	°			
72 (51)	July 4 — Sept. 12	248	18	122, 124	Q. 3	Radiant rather diffuse, and elongated? Heis incorrect?
	July 1-15	262	12	Q 3	Heis	
73	July 4-11?	210	20	Q 4	G. & H.	Confirmed also by Zezioli's obs., and reduced by Mr. Greg.
74	July 16	257	36	Q H	G. & H.	Observed by Prof. Herschel, 16 July, 1871. Perhaps = Q 3.
75 (93)	July 24 — Aug. 11	330	88	115, 135?, 143	S. & Z.	Radiant well defined, close to *Polaris*. At 10° + 83 in 1871.
	July 28 — Sept. 10	359	90	N 12, 13	G. & H.	
	July 1 — Aug. 31	220	85	N 11, 12, 13, 14	Heis	
76	July 18 — Aug. 4	344	40	98, 100, 103, 104, 106, 113, 123, 134	S. & Z.	Radiant multiple. Centre of group near *η Pegasi*; at *μ Pegasi* in 1872.
	Aug. 3-15	337	25	T G	G. & H.	
77	July 2 — Aug. 16	342-34		H	G. & H.	= Y_1 of Neumayer and Heis? Southern Hemisphere radiant near *Fomalhaut*, observed by A. S. Herschel, 28 July, 1865. Also seen in England, Aug. 9-11, 1871.
78	July 11 — Aug. 7	7	50	93, 111, 129, 130, 138	S. & Z.	From Zezioli's obs. (A. 9). Possibly with R 1, 2 of G. & H.
	July 4-11?	7	42	A 9	G. & H.	
79	July 28	174	55	118	S. & Z.	A well-defined radiant and meteoric shower, 1869-71. Maximum about 10th of August.
	July 29 — Sept. 6?	165	53	V	G. & H.	
80 (68)	July 21	309	40	109?	S. & Z.	Possibly connected with No. 68.
	July 4 — Aug. 22	315	31	B G	G. & H.	
81	Aug. 15-31	314	15	T 1	Heis	Heis, position probably incorrect.
82	July 30 — Aug. 4	33	34	125, 132	S. & Z.	
83	July 9-21	242	68	91, 96, 108?	S. & Z.	Radiant well defined.
	July 12-31	245	64	B Z	G. & H.	
84	July 21	11	38	110	S. & Z.	Requires further investigation as to Epoch and duration.
	July 28 — Sept. 3?	1-15	36	R 1, 2	G. & H.	
85	Aug. 6-12	45	51	137, 139, 142, 144	S. & Z.	N.B. The Perseids have an elongated radiant area extending from *Perseus* to *Cassiopeia*. = Comet III. 1862.
	Aug. 10-12	50-30	49-64		Serpieri	
	July 28 — Aug. 15	50-25, 44	50-65, 56	A 10	G. & H.	
	July 15? — Aug. 15	51	55	A 10, 11	Heis	
86	Aug. 6	254	37	136	S. & Z.	
87	Aug. 10	47	18	140	S. & Z.	
88	Aug. 10-11	3	17	(Tacchini)	S. & Z.	Possibly a pseudo-radiant of T 1 and Perseids; or a commencement of $T_{2, 3}$.
	Aug.	355	18	T 1 *a*	G. & H.	
89	Aug. 22 — Oct. 15?	359	17	T 2, 3, (4?)	G. & H.	= Σ_2 of Neumayer and Heis, at 346 + 3 for Sept.
	Sept. 1-30	352	10	T 2, 3	Heis	

Epoch or Duration of Meteoric Shower.	Average Position of Radiant. R.A.	N.D.	Name or Number of Radiant.	Authority.	Observations. (N.B. Radiant Area supposed to be 15° in Diameter. Radiants, "Z," by Mr. Greg, from Zezioli's Observations.)
	°	°			
Aug. 28	340	65	94, 145	S. & Z.	Exact duration uncertain. Radiant precise. Perhaps connected with No. 65 or 96.
Aug. 6-31?	335	67	E 1	G.&H.	
Aug. 2 — Sept. 25	285	44	B 5	G.&H.	Well-marked shower; radiant well defined.
July 29-31	276	36	122, 124	S.&Z.	
Aug. 15 — Sept. 30	38	63	A 12, 13, 14	Heis	G. Forbes, Cambridge, Aug. 10, 1868 = 33° + 59°.
Sept. 19 — Oct. 20	10	88	N 14	G.&H.	Probably continuation of N 12, 13.
Sept. 1 — Oct. 15	100	85	N 15, 16, 17	Heis	
Sept. 6 — Oct. 12	55	33	147, 150, 155	S. & Z.	
Oct. 14 — Nov.?	46	27	R 3?	G.&H.	
Sept. 1 — Oct. 15	48	34	R 1, 2, 3	Heis	
Sept. 1 — Oct. 15	306	62	B 7, 8, 9	Heis	
Sept. 5-20	319	53	146, 151	S. & Z.	Epoch requires further investigation, perhaps = No. 95. A well-marked shower in September.
Aug. 10 — Sept. 30?	335	52	E 2	G. & H.	
Sept. 7-12	60	65	148, 149	S. & Z.	
Sept. 23	28	35	152	S. & Z.	
Sept. 6 — Nov. 23?	17	10	U	G.&H.	A southern radiant. Well observed 27th Sept. 1864, by A. S. Herschel, in Kent.
Sept. 28 — Nov. 10	82	49	153, 162, 166	S. & Z.	Multiple radiant; centre about 82° + 50°. An important and well-defined meteoric shower, with tendency to advance with the time from 75° + 45° to 90° + 54°.
Sept. 17 — Nov. 24	83-92	50-55	F 1, 2	G.&H.	
Oct. 16-31	72	44	A 16	Heis	
Oct. 1-15	57	61	A 15	Heis	
Oct. 5	240	63	154	S. & Z.	
Oct. 21	130	48	159	S. & Z.	
Oct. 3-20	142	44	L G	G.&H.	
Oct. 13-21	84	21	156, 157, 158, 160	S. & Z.	Tacchini, 21st Oct. 1867; radiant 74° + 25°. Maxm. 18-21 Oct. A well-marked shower; radiant precise at ν *Orionis*. Maxm. 18-20 Oct.
Oct. 17 — Nov. 13?	90	15	O	G.&H.	
Oct. 23	111	29	161	S. & Z.	
Oct. 28	110	70	163	S. & Z.	
Oct. 16-31	205	85	N 18	Heis	
Oct. 16-31	334	56	B 10	Heis	
Oct. 16-31	23	40	P 1	Heis	A doubtful radiant.
Oct. 18-29	283	43	B G 6	G.&H.	More observations required for this shower.
Nov. 10	70	20	165	S. & Z.	Mr. Backhouse 4-6 Nov. 1869, radiant = 54° + 16°; also observed at Greenwich 13th Nov. 1870 at 55° + 25°. Generally a well-marked shower at α *Tauri*.
Oct. 25 — Nov. 21	64	18	R G 2	G.&H.	
Nov. 1-15	55	16	R 4	Heis	

Progressive No. 1872, (R. P. Greg.)	Epoch or Duration of Meteoric Shower.	Average Position of Radiants. R.A.	Average Position of Radiants. N.D.	Name or Number of Radiant.	Authority.	Observations. (N.B. Radiant Area supposed to be 15° in Diameter. Radiants, "Z," by Mr. Greg, from Zezioli's Observations.)
		°	°			
112	Oct. 31 — Dec. 12	134	6	L H	G. & H.	
113	Nov. 9	61	42	164	S. & Z.	
114	Nov. 12-13	359	37	168, 170	S. & Z.	
115	Nov. 13-15	149	23	L	G. & H.	Leonids identical with Comet I. 1866.
	Nov. 13-15	148	24	L	Heis	
116	Nov. 23 — Dec. 9	291	53	D G 3	G. & H.	
	Nov. 1-15	279	56	D ?	Heis	
117	Nov. 13-14	33	40		Denza	Observed by Prof. Denza, 1870 (Query pseudo radiant of = A 16, P 2, 3 or R 3 ?)
118	Nov. 13-14	40	60	171	S. & Z.	Connected with R 3? No. 171 probably a pseudo-radiant. Requires further investigation.
	Nov. 23 — Dec. 18	45	55	A 16	G. & H.	
	Oct. 16 — Nov. 30	46	44	P 2, 3	Heis	
119	Nov. 12-17	117	38	169, 172	S. & Z.	
120	Nov. 30	17	48	176	S. & Z.	Radiant probably elongated. Supposed by D'Arrest and Weiss to be connected with Biela's Comet.
	Sept. ? — Nov. 25 ?	7-23	54-61	A 14, 15	G. & H.	
	Nov. 1 — Dec. 15	17	60	A 17, 18, 19	Heis	
121	Nov. 10 — Dec. 9	142	36	167, 173, 177, 178, 181	S. & Z.	
122	Nov. 13	193	40	No. 122	G. & H.	Observed at Greenwich, 1870: radiant near *Cor Caroli*. A doubtful radiant.
123	Dec. 23	157	64	187	S. & Z.	Radiant elongated 140°, + 70° to 170°, +72°. Shower well marked.
	Nov. 4 — Dec. 19	160	71	K G	G. & H.	
124	Nov. 19 — Dec. 15	123	84	N 19, 20	Heis	
125	Nov. 23-26	103	32	174, 175	S. & Z.	An important meteoric shower: maxm. 11th Dec. Radiant centre δ *Geminorum*. Radiant at 105° + 30°, 12th Dec. 1861: R. P. Greg and A. S. Herschel: Mr. Wood at 100° + 34° in 1863. Probably elongated 90° + 40° to 105° + 28°. Aërolitic epoch.
	Nov. 26 — Dec. 30	100	33	G_1	G. & H.	
	Dec. 1-15	112	39	M 9	Heis	
126	Dec. 9	154	26	182	S. & Z.	
127	Dec. 9-21	108	63	179, 180, 184?	S. & Z.	
128	Dec. 12	180	53	183	S. & Z.	
129 (7)	Dec. 23	157	64	187	S. & Z.	Possibly commencement of No. 7 (Jan. 6.)
				? G_2	G. & H.	

Supplementary Radiants.

130	Aug. 1-31	337	−10	Σ 2	Heis	A southern radiant in the list of Heis and Neumayer; observed in England 9-12 Aug. 1871.
131	Aug. 3-30	68	46	F G	G. & H.	Reduced from the observations at the Radcliffe Observatory at Oxford in 1870-71. The Radiant was also observed simultaneously.
132	Aug. 3-15	55	26	R G 1	G. & H.	

In making or reducing meteor observations, note on a single night, or on two or three consecutive evenings, it is always best to map the results *at once*, and either to endeavour to determine any new radiant, or to correct the position of old-established ones; making use of this catalogue as a guide, rather than as an end. There being doubtless a tendency for particular meteor-showers to appear most strongly marked on certain special dates, it will thus be possible to determine the position of their radiant points more accurately than they are frequently at present known. Observations specially directed towards the supposed position of a radiant will also best show the shorter tracks, which are best calculated to determine the precise position of the radiant point of any particular meteor-shower: and the characteristic features of speed or duration, brightness, colour, and of the attendant sparks or streak of meteors belonging to different showers should at the same time be very carefully recorded, and considered in distinguishing the radiant points from which they probably diverged. The radiant V, and probably also T G (No. 78), seems to have appeared somewhat prominently only during the last two or three years; whilst the neighbouring radiant T 1 (No. 67), formerly a prominent feature, especially during the August period, and giving meteors considerably less rapid in their flight than the Perseids, have been less noticeable. Those meteor-showers, at present most clearly marked and contemporaneous with the greater 7–12th August period, are V; T G (78); N 12, 13; E 1 (90); B 3; H (77); B 4 (68); T 1 (67); and in mapping the meteors at that period it will be well to bear those radiants in mind whilst attempting to fix with any degree of precision the true radiant centre (probably in itself not a fixed or precise one) of the Perseids themselves. The series of well-marked and nearly contemporaneous meteor-showers from July to September, with radiant centres some 15°–20° around, is near *α Cephei*, including E 1; E 2; B 1, and B 4 of Greg and Herschel; B 3, B 4, and B 5 of Heis, and mostly corroborated by the Italian observers, are deserving of more study, whether as to precise duration or exact position of radiant centres and connexions with each other; or as appertaining to a single multiple radiant, or to several distinct centres of radiation.

R. P. G.

Observations of Meteor Showers, supposed to be connected with Biela's Comet. By Prof. A. S. Herschel, F.R.A.S.

In a recent publication by Dr. Weiss* on the lately discovered connexion between the appearances of meteoric showers and the orbits of certain comets, a suggestion of some importance to observers of shooting stars is offered, to which the present year

* *Beiträge zur Kentniss der Sternschnuppen;* Vienna Acad. Sitzungsbericht, vol. lvii. 1868.

affords a most suitable opportunity for directing their attention. It is well known that on the occasion of its perihelion return in the year 1832, it was pointed out by Olbers that the nucleus of Biela's comet would pass within 20,000 miles of the Earth's orbit, at a point which the Earth would occupy on about the 3rd of December in that year. Had the comet passed its descending node on that date, instead of actually about one month earlier, some particles of its substance would doubtless have entered into collision with the Earth's atmosphere, and would probably have given rise to a considerable meteoric shower. The direction of their motion relatively to the Earth (or the radiant point of the cometary shower) would, it is calculated by Dr. Weiss have been, in that case, from a point in about R.A. 23°, N. Decl. 47°; and this point would have appeared to be the centre of divergence of a shower of shooting stars. It is remarkable that a meteoric shower having nearly this radiant point has been repeatedly observed since the earliest recorded appearance of Biela's Comet, on the nights of the 6th or 7th of December, of whose appearance previously to that time no record is known to exist, although a search for its occurrence was made by Prof. Newton in the best, and most extensive catalogue of meteor-showers of earlier dates.* Its first, and apparently most brilliant display was observed by Brandes, in Germany, in the year preceding the appearance of the great November star-shower recorded by Humboldt and Bonpland in America at the end of the last century, of which shower, to judge from the description of it given by Brandes, it was, indeed, by no means an insignificant precursor. It was afterwards reobserved on the same date (December 7th) in the year 1830, in France; and again in France, Belgium, and the United States in 1838, the meteors being on this occasion about four times as frequent as on an ordinary night; and by Prof. Heis at Aix-la-Chapelle in 1847, since which time no distinct account of its reappearance on the same dates seems to have been recorded. The date of its appearance in each of the years 1838 and 1847, was on the evening of the 6th of December.

At its return in 1838, the position of its radiant point was fixed by Herrick, in the United States, as in some part of *Cassiopeia's* Chair; by M. Flaugergues in France, somewhat south of this, in *Andromeda;* and by M. Bouvy, at the observatory at Brussels, near the zenith, which was there situated at the time of the observation between *Cassiopeia* and *Andromeda.* Its approximate position, as noted by Prof. Heis at Aix-la-Chapelle, in 1847, was at a point in R.A. 25°, N. Decl. 40°, not far from the star of *γ Andromedæ.* Later observations appear to have led Prof. Heis to adopt a more northerly position (A 19 in his later list of radiant points for December) at R.A. 21°, N. Decl. 54°. This shower is therefore as totally distinct, both in its date and comparatively rare returns, as in the position of its radiant point from the far older, annually recurring, and

* *American Journal of Science,* Second Series, vol. xxxvi., p. 145, *et seq.*

better known meteor shower of the 12th of December, whose radiant point has recently been determined with certainty and precision in the neighbourhood of *θ Geminorum*, in R.A. 105°, N. Decl. 30°. As shown by Prof. Newton in his already mentioned research, the earlier appearances of this shower also extend backwards as far as the year A.D. 901.

A radiant point of several shooting stars, observed by Mr. Zezioli in Italy on the evening of November 30, 1867, is contained in Prof. Schiaparelli's list of radiants derived from Mr. Zezioli's observations (as shown in Mr. Greg's comparative table) at R.A. 17°, N. Decl. 48°, near *θ Cassiopeiæ*. An elongated region of radiation of shooting stars, lasting for a long period until near the end of November (A 14, 15 in the English list), is there also placed by Mr. Greg close to the position of the radiant A 19 of Prof. Heis, although preceding it considerably in point of time. But it appears not impossibly to be connected by intermediate meteors with the succeeding radiant A 16 in the same list, whose position is somewhat too distant to be included in the former group. The node of the orbit of Biela's comet possessing an extremely rapid retrograde motion, so that the date of the Earth's passage through it now falls in the end of November instead of in the beginning of December, it appears probable that the dates of the last two meteoric showers, although not coinciding with the 6th or 7th of December, may yet have belonged to returns of the cometary meteor group. The following longitudes and dates of the Earth's passage through the node, and the corresponding positions of the cometary radiant point from the earliest to the latest recorded appearances of Biela's comet, were calculated by Dr. Weiss from Hubbard's elements of the comet's orbit at those times of its appearance. The mean motion of the node of a meteoric cloud revolving in the same orbit as that of Biela's comet, arising from the planetary perturbations, if calculated in the same manner for the 7th of December meteors as that calculation was successfully accomplished by Prof. Adams for the December meteor group, would indicate, as suggested by Dr. Weiss, the extent to which such a meteor cloud may be expected to participate with Biela's comet in the rapid retrograde displacement of its node.

Year of Observation.	Longitude of Desc. node. (1850·0).	Date of Earth's Passage through Node.	Position of Cometary Radiant Point. R.A.	N. Decl.	Velocity of the Meteor relatively to the Earth.
	°		°	°	
A.D. 1772	258·4	Dec. 10	18·7	58·1	9·6 miles per second.*
„ 1826	251·8	Dec. 4	22·8	47·7	9·6 „ „
„ 1852	245·8	Nov. 28	23·4	43·0	9·7 „ „

* These velocities are without allowing for the effect of the Earth's attraction. When this is taken into consideration the relative velocity of the meteors of Biela's comet is found to be 11·9 miles per second, while that of the Leonids, or meteors of the November shower, is 44·3 miles per second.

Owing to the comet's motion in its orbit, and that of the Earth being in the same direction, and but slightly inclined to each other (about 22°), at their point of nearest approach, the case of this meteor stream overtaking the Earth is a somewhat extreme example of the opposite kind to that of the November meteor current, which meets the Earth with a small inclination to its course, moving in an opposite direction. The speed with which the meteor particles of Biela's Comet enter the Earth's atmosphere (allowing for the effect of the Earth's attraction) is thus little more than a fourth part of that with which the November meteors first penetrate it. Their radiant point is, for the same reasons, more westerly than those of ordinary meteor showers, arriving near the zenith at Greenwich soon after eight o'clock in the evening, and descending towards the north-west and north horizon (where it is circumpolar) during the later hours of the night. In its approach to the northern horizon (should the meteors be observed in the early morning hours), the effect of the Earth's attraction upon their nearly horizontal courses, owing to the extremely low relative velocity presented in the case of this westerly meteor current, is so considerable that the apparent radiant point is raised about 10° from the apparent position which it has when the radiant point of the shower is in the zenith.

Besides the disruption of Biela's comet into two parts, which was witnessed during its reappearance in the year 1832, it is observed by Dr. Weiss that the approximate orbit of the telescopic Comet I. 1818, appears to coincide so nearly with that of Biela's comet, that should it be a fragment of that comet formerly separated from its principal body, and now revolving in nearly the same periodic time with it, but passing its perihelion somewhat more than one year earlier than Biela's Comet, the star-showers of December 1798 and 1838, would be found to coincide with the dates of perihelion passage of this companion comet at the beginning of those years in the same way that the great star-showers of August 1863, and November 1866, followed quickly after the appearances of the Comets III. 1862, and I. 1866. In the following list of the approximate dates of the former and present passages of Biela's comet (and of Comet I. 1818) through its node, it will be seen that one of the December meteor-showers was similarly observed in 1847, following one of the nodal passages of Biela's comet in the preceding year; and that the shooting-stars from *Cassiopeia*, observed by Sig. Zezioli in Italy on the 30th of November, 1867, appeared in the year following the return of Biela's Comet to its node in the year 1866.

Should a clear sky permit a watch to be kept for these meteors during the last week in November, and the first week in December next, and especially on the nights of the 4th to the 7th of December, both in this and in next year, a favourable opportunity for verifying practically these ingenious suggestions of Dr.

Weiss presents itself in the occasion of the present return of Biela's Comet, which it may be hoped will not escape the attention of astronomers, nor pass unnoticed by observers and recorders of meteoric showers.

Dates and Places of Observation of the Great Meteor Shower of Brandes, of the 6th and 7th of December.	Approximate Dates of the Passage of Biela's comet (and of Comet I. 1818) through its Node.
A.D 1798, Dec. 7 (P.M.). Great shower of meteors observed by Brandes, near Hamburg, Germany. Four hundred meteors counted in a few hours (in half of the sky, while travelling). Benzenberg, *Die Sternschnuppen.*	A.D. 1799·3 (1798·1; Comet I. 1818?).
1830, Dec. 7 (P.M.). Many shooting stars seen in France, by Abbé Raillard. *Comptes Rendus*, 1839, Feb. 4.	1832·8 (1831·4; Comet I. 1818?).
1838, Dec. 6 (P.M.). Meteor shower observed in France, at Toulon, by Paul Flaugergues; and in the United States by E. C. Herrick. Seen also at Brussels, by M. Bouvy, Assistant at the Observatory, from $7^h\ 30^m$ P.M. Meteors four times as frequent as on an ordinary night, descending from *Pegasus* and *Aries* towards the S.E. and S.W. horizon from the direction of the zenith, [*i.e.*, from near *Cassiopeia;* radiant in *Cassiopeia.*] *Comptes Rendus*, 1839, Jan. 21, and Feb. 4 (*Bulletins*, Ac. Roy. de Belgique, vol. vi., No. 6, June, 1839).	1839·4 (1838·1; Comet I. 1818?).
1847, Dec. 6 (P.M.). Shower of meteors observed by Prof. Heis, at Aix-la-Chapelle. Radiant point at R.A. 25°, N. Decl. 40° [near γ *Andromedæ.*] Heis, *Die Periodische Sternschnuppen*, Cöln, 1849.	1846·1 (Biela's comet separated into two parts.
1867, Nov. 30 (P.M.). Nine meteors in two hours recorded by M. Zezioli at Bergamo, Italy; all radiating nearly from a point in R.A. 17°, N. Decl. 48°, near θ *Cassiopeiæ.* Prof. Schiaparelli; Preliminary results of Shooting-star observations made by Zezioli, Part II. *Effemerides Astronomiche del Osservatorio di Milano*, 1871.	1866·0 (Biela's comet not seen since 1852. Present nodal passage of [Biela's comets 1872·7; of Comet I. 1818, 1871·4?).

Dr. Huggins's Spectroscopic Observations of Stars and Nebulæ.

Dr. Huggins has communicated to the Royal Society a series of results of extreme interest, obtained by means of the fine telescope placed at his disposal by the Royal Society.

His work has been divided into two main portions. First, he has been engaged in comparing one of the bright spectral lines of

the gaseous nebulæ with the corresponding line in the spectrum of nitrogen. This line, as seen in the latter spectrum, is double. When using his own 8-inch telescope, Dr. Huggins was unable to determine whether the nebula line was double or not. He could not use sufficient dispersive power. He has now obtained definite results on this point, so far at least as the *Orion* nebula is concerned. In the spectrum of nitrogen the components of this double line are rather broad and nebulous. In the spectrum of the *Orion* nebula there is one line, narrow and well defined, which agrees in position with the less refrangible of the nitrogen pair. There are two available explanations of this. It may be that under certain conditions the line becomes single, occupying a position midway between the positions of the two lines, and that in the spectrum of the *Orion* nebula the line is shifted owing to the motion of the nebula. A motion at the rate of from 30 to 40 miles from the Earth would account for the displacement. Or again, it may be that under certain conditions the more refrangible line might fade out altogether. Dr. Huggins has tried the experiment, but has not been able to reduce the spectrum of nitrogen to a single line. The observations required are somewhat difficult, as the lines fade out under the change of condition which alone seems to promise to effect the simplification of the spectrum. But Dr. Huggins feels tolerably certain that the line is always double, and that there is no change in its position.

It is possible, however, Dr. Huggins remarks, that this line in the spectrum of the gaseous nebulæ is not due to nitrogen at all. Or else, one line of nitrogen fades out altogether. He proposes to compare the spectrum of nitrogen with the spectra of other gaseous nebulæ.

The second series of results obtained by Dr. Huggins relates to the determination of the stellar motions of recession or approach. In making these observations, Dr. Huggins has not trusted to the ordinary method of comparing spectra by placing a prism over one half of the slit, and so bringing the spectrum of comparison beside that of the star under examination. He points out that this method is in several respects unsatisfactory. Indeed, he did not trust solely to this method in his former observations of *Sirius*. He set a light directly opposite the object-glass of his telescope, and compared its spectrum with that of the star. But with a telescope 15 feet long, like that which he is now employing, this arrangement is not convenient, and the light is rendered by distance too faint for his purpose. He has therefore had holes drilled in the telescope tube, 30 inches from the focus, and causes a holder containing a vacuum tube to be placed exactly in the optical axis of the telescope. Instrumental means exist for accurately adjusting the vacuum tube in this position; but the accuracy of the adjustment can also be very readily tested.

Dr. Huggins had judged when he used his 8-inch telescope that *Sirius* is receding at the rate of about 25 miles per second.

He now finds that the rate of recession is somewhat less, lying probably between 18 and 22 miles per second.

He has been able to extend this method to several other stars. He finds evidence in favour of a general tendency to recession in stars occupying that part of the heavens from which our Sun is known to be travelling; while on the opposite side of the heavens the stars seem in general to be approaching. But the rates of recession and approach accord very ill with the usually adopted value of the solar proper motion, and appear to support the theory recently advanced, that the estimates of the stellar distances, on which that value has been based, are not trustworthy. We know that the Sun's rate of motion has been set at five or six miles per second, and such a rate of motion could only account for a general excess of recession in stars lying in one direction, and of approach in stars lying in the opposite direction, by about the same amount. But Dr. Huggins finds motions of recession of from 15 to 28 miles per second, and motions of approach amounting even to the enormous rate of 55 miles per second in the case of *Arcturus*. It would seem to follow from this that Struve's estimate of the average distances of the brighter stars is altogether too low.

The following tables are from Dr. Huggins's paper:—

Table I. Stars moving from the Sun.

Star.	Compared with	Apparent Motion.	Earth's Motion.	Motion from Sun.
Sirius	H	26 to 36	−10 to −15	18 to 22
Betelgeux	Na	37	−15	22
Rigel	H	30	−15	15
Castor	H	40 to 45	−17	23 to 28
Regulus	H	30 to 35	−18	12 to 17
β Urs. Maj.	H			
δ —	H			
ε —	H	30	−9 to −13	17 to 21
γ —	H			
ζ —	H			
ζ Leonis	H			
δ —	H			
η Urs. Maj.	H			
α Virginis	H			
α Coronæ B.	H			
Procyon	H			
Capella	H			
Aldebaran (?)	Mg			
γ Cassiopeiæ	H			

Table II. Stars approaching the Sun.

Star.	Compared with	Apparent Motion.	Earth's Motion.	Motion towards Sun.
Arcturus	Mg	50	+ 5	55
Vega	H	40 to 50	+ 3·9	44 to 54
α Cygni	H	30	+ 9	39
Pollux	Mg	32	+17	49
α Ursæ Maj.	Mg	35 to 50	+11	46 to 61
γ Leonis	Mg			
ε Bootis	Mg			
γ Cygni	H			
α Pegasi	H			
γ Pegasi (?)	H			
α Andromedæ	H			

It will be seen that the five stars β, γ, δ, ε, and ζ, are all receding at the rate of about 30 miles per second. Moreover, Dr. Huggins finds that the spectra of all these stars present similar characteristics, the lines of hydrogen being very broad and strong. In η *Ursæ Majoris* the line of hydrogen is not so strong or so broad, nor is η receding at the same rate; so that clearly this star does not belong to the same set. The star α *Ursæ* is found to have a spectrum markedly different from that common to β, γ, δ, ε, and ζ, and to be approaching the Earth instead of receding. This agrees with the theory recently advanced, that the five stars, β, γ, δ, ε, and ζ, form a drifting group of stars.

Sweeping Ephemerides for the Comet of Biela, including the Period of Absence of Moonlight in the Morning Sky in October. By J. R. Hind, Esq.

1872.

	$9^h\ 36^m$ Perihelion, Sept. 28·4.			Perihelion, Oct. 6·4.			Perihelion, Oct. 14·4.	
G.M.T.	R.A.	Decl.		R.A.	Decl.	Δ	R.A.	Decl.
	h m	° ′		h m	° ′		h m	° ′
Sept. 28	10 4·0	+6 27		9 43·0	+9 15	1·345	9 20·3	+12 22
30	13·0	5 21		9 52·4	8 6		30·2	11 9
Oct. 2	21·9	4 15		10 1·7	6 56	1·365	40·0	9 56
4	30·7	3 9		10·9	5 46		49·7	8 42
6	39·3	2 4		19·9	4 37	1·388	9 59·2	7 28
8	47·8	+1 0		28·8	3 28		10 8·6	6 15
10	10 56·2	−0 3		37·6	2 20	1·414	17·8	5 2
12	11 4·5	1 4		46·2	1 13		26·9	3 50
14	12·6	2 5		10 54·8	+0 7	1·442	35·8	2 38
16	20·6	3 4		11 3·2	−0 58		44·6	1 27
18	11 28·5	−4 2		11 11·4	−2 2	1·472	10 53·3	+ 0 18

Mr. Bishop's Observatory,
Twickenham, 1872, Sept. 17.

Discovery of two New Minor Planets (122) *and* (123).

By Prof. C. H. F. Peters.

(*From a Letter to the Astronomer Royal.*)

Of two unknown planets, found both on the night of July 31, and which may be called (122) and (123) provisionally, I have succeeded in making the following observations (omitting a rough estimation of position of (123) on the first night) :—

1. *Planet* (122).

1872.	H. C. M. T.	App. α	App. δ
	h m s	h m s	° ′ ″
July 31	15 9 37	21 48 56·47	− 11 41 54·9
Aug. 1	11 32 49	48 22·36	45 1·8
2	12 42 0	47 39·73	48 57·4
3	12 1 16	46 59·52	52 38·2
4	12 1 18	46 17·64	11 56 31·0
5	11 57 8	45 35·47	12 0 21·1
7	12 7 10	44 9·32	8 13·1
8	11 9 40	21 43 28·11	− 12 12 4·4

2. *Planet* (123).

1872.	H. C. M. T.	App. α	App. δ
	h m s	h m s	° ′ ″
Aug. 1	12 8 29	21 57 30·53	− 10 4 55·3
2	13 22 13	56 39·73	6 42·3
4	11 31 8	55 4·91	10 15·5
5	12 53 38	54 11·34	12 15·0
7	13 8 15	52 27·13	16 16·9
8	12 2 38	21 51 37·20	− 10 18 17·3

The magnitude of (122) I estimated 11·5, that of (123) a little less, perhaps 12·0.

Litchfield Observatory of Hamilton College,
Clinton, N. Y., Aug. 9, 1872.

Discovery of Minor Planet (124).

By Prof. C. H. F. Peters.

(*From a Letter to Sir G. B. Airy, Astronomer Royal*).

Another new planet was found on 23 August, bright, of tenth magnitude. I communicate the following positions of the same, obtained by the filar micrometer:

1872.	Ham. Coll. M.T.	α (124)	δ (124)	No. of Com.
	h m s	h m s	° ′ ″	
August 23	12 28 7	22 21 23·61	− 7 18 28·8	10
„ 24	13 22 50	22 21 21·66	7 18 42·3	5
„ 25	12 7·44	22 19 44·45	− 7 30 13·4	10

Litchfield Observatory of Hamilton College,
Clinton, Oneida Co., N. Y., August 26, 1872.

Discovery of a Minor Planet (125). By M. Prosper-Henry, Assistant-Astronomer of the Paris Observatory.

The observed position was

1872, Sept. 11, $15^h\ 47^m\ 35^s$, Paris M.T. R.A. $23^h\ 59^m\ 33^s$. S. Dec. $0°\ 55'\ 57''$
Hourly motion in R.A. = $-\ 1^s{\cdot}9$ (deduced from half-an-hour's observation).
Hourly motion in D = $-\ 20''$.

Magnitude about 11·7.

The comparison star was 4612 of Argelander's zones.
The number of this planet will be provisionally (125).

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